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ABSTRACT

This publication is a syllabus for a senior high school chemistry course designed for the average ability, nonscience major. The content of the syllabus is divided into three basic core areas: Area I: Similarities and Dissimilarities of Matter (9 weeks); Area II: Preparation and Separation of Substances (10 weeks); Area III: Structure and Properties of Simple Organic Compounds (2 weeks). A minimum of two optional areas, each lasting for 6 weeks, are to be selected from these topics: Further Study of Organic Compounds; Chemistry in the Home; Water and Air Pollution; and Some Modern Materials and their Uses. It is recommended that there be a minimum of five 45-minute periods per week, with an average of three periods per week devoted to laboratory activities. The syllabus organization includes a listing of topics, an outline of basic concepts to be introduced, suggestions and references for laboratory activities, and supplementary information including amplification and explanation of the basic concepts. The use of this syllabus does not mandate the selection of any particular textbook or laboratory manual. First year algebra is a prerequisite for this course. The appendices include descriptions of the suggested laboratory activities, a bibliography of chemistry references, and a listing of films and filmstrips. (PR)

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chemistry

The University of the State of New York
THE STATE EDUCATION DEPARTMENT
Bureau of Secondary Curriculum Development Albany

GENERAL CHEMISTRY

-- A State course of study for credit
as a Group 3 elective toward a
State Regents High School Diploma

1970 Edition

The University of the State of New York/The State Education Department
Bureau of Secondary Curriculum Development/Albany, New York 12224

THE UNIVERSITY OF THE STATE OF NEW YORK

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FOREWORD

This tentative syllabus represents an attempt to develop a suggested St
chemistry. As indicated on the cover, this course is intended for nonscienc
a senior high school course in chemistry. The Regents course in chemistry,
3-unit, Group 2, major sequence or as an elective, serves the needs of the h
student. This course in general chemistry is mainly for the average student
be different from those who take the Regents chemistry course.

The past decade has seen many important changes in the science courses
There is greater depth of treatment in the new science 7-8-9 program. As a
science syllabuses have been revised to limit the range of content to permit
understanding. Obsolete content has been eliminated from the new courses.
A basic core of required material with optional extended areas has provided
treatment. New and more appropriate laboratory experiences have been introd
quantitative and analytical investigations.

At the same time the holding power of the secondary school has continue
pupil population with an ever widening range of interests and abilities. Th
a significant percentage of students take no chemistry beyond the ninth year
counselors, and administrators have recommended that the Department develop
with an optional State examination. These recommendations were adopted by t
and this office, and have led to this publication.

A committee was appointed and convened in May 1966 to consider the prob
to the nature and framework of such a course. This committee consisted of t
diverse areas of the State who were experienced with local and national scie
of the committee were: Daniel Beckett - Hempstead High School; Joseph Bovan
Howard Facklam - Amherst Central High School, Snyder; Milton Goodman - Westc
Ellis Katzman - Erasmus Hall High School, New York City; William Kelley - Th
Joan Leonard - Bay Ridge High School, New York City; Joseph Marcelli - Hudso
Leonora Pugh - Cochran School of Nursing, Yonkers; and Robert Wiechman - New

During the spring of 1967, a committee of high school chemistry teachers
syllabus. The members of this committee are: Anthony Anacreonte - Plainedg
Citriniti - Sauquoit Valley Central School; Harold Dorf - Midwood High Schoo
Amherst Central School, Snyder; Elizabeth Lamphere - Norwich Central School;
Anthony A. Henninger High School, Syracuse. The framework developed at the
Miss Lamphere, reviewed by the members of the committee, and served as the b
of a new syllabus.

FOREWORD

resents an attempt to develop a suggested State course of study for general
cover, this course is intended for nonscience majors who would benefit from
hemistry. The Regents course in chemistry, used for credit as part of the
or as an elective, serves the needs of the high average and above average
chemistry is mainly for the average student whose interests and goals may
the Regents chemistry course.

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has been eliminated from the new courses. Some new content has been added.
l with optional extended areas has provided teachers with time for depth
iate laboratory experiences have been introduced to permit extensive
stigations.

g power of the secondary school has continued to increase, there has emerged a
dening range of interests and abilities. Then, too, there is the fact that
ents take no chemistry beyond the ninth year. As a result, many teachers,
ave recommended that the Department develop a general course in chemistry
on. These recommendations were adopted by the Bureau of Science Education
this publication.

nd convened in May 1966 to consider the problem and make recommendations as
uch a course. This committee consisted of teachers and supervisors from
ere experienced with local and national science curriculum programs. Members
eckett - Hempstead High School; Joseph Bovan - Vestal Central School;
High School, Snyder; Milton Goodman - Westchester Community College, Valhalla;
h School, New York City; William Kelley - The Fox Lane School, Bedford;
hool, New York City; Joseph Marcelli - Hudson Valley Community College, Troy;
Nursing, Yonkers; and Robert Wiechman - New Rochelle Hospital-Nursing.

committee of high school chemistry teachers met to develop this chemistry
ommittee are: Anthony Anacreonte - Plainedge Public Schools; Vincent
ral School; Harold Dorf - Midwood High School, New York City; Howard Facklam -
Elizabeth Lamphere - Norwich Central School; and E. Dorothy Swindells -
, Syracuse. The framework developed at the first meeting was expanded by
embers of the committee, and served as the basis for the experimental draft

During the summer of 1967, Miss Lamphere, serving as a consultant to the
Development, worked under the direction of John V. Favitta, Associate in Scie
new course. Robert G. MacGregor, formerly Associate in Science Education and
Education, reviewed the manuscript and made valuable suggestions. This exper
small number of schools in the State during the 1967-68 school year.

This draft was revised during the summer of 1968 on the basis of the exp
in the experimentation, and on the recommendations made by the syllabus commi
prepared by W. Allister Crandall, Pulaski Central School, and Miss Lamphere,
of Mr. Favitta. The final edition of the syllabus, reflecting feedback from
3 years, was prepared during the summer of 1970 by Orson W. Dunham, Guilderla
Douglas C. Franke, Colonie Central High School, working with Mr. Favitta.

It is not the intent of this syllabus to mandate the selection of any pa
guide. Most teachers will find it desirable to rely on multiple references r

Reactions to this draft are welcome. They should be addressed to the Bu
one of the Bureaus listed below.

Gordon E. Van Hooft
Chief, Bureau of Se
Curriculum Developm

William E. Young
Director, Curriculum
Development Center

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Gordon E. Van Hooft
Chief, Bureau of Secondary
Curriculum Development

OVERVIEW

Aims and content of the general chemistry course

This course of study presents an approach to the study of chemistry which may be more useful to some pupils than the Regents chemistry course. An effort has been made to provide pupils, not majoring in high school science, with a course of study that may better prepare them to meet their special goals in life. In addition, the course helps to provide pupils with an increased understanding of the work of the chemist.

The objectives of this course in chemistry should extend beyond a minimal comprehension of the basic facts and principles outlined in this syllabus. *The laboratory approach should be stressed and understandings should come out of laboratory experiences whenever possible.* The appreciation of scientific methods, the ability and willingness to change beliefs and opinions after careful weighing of new evidence, and the development of the habit of critical thinking are the intangible, but important, outcomes of this course.

State diploma credit

This course may be used as one unit of Group III credit as an elective toward a New York State Regents high school diploma. *This course may not be used as one unit of credit for the Group II major science sequence toward a New York State Regents high school diploma.*

Sequence and scheduling

In an attempt to introduce some degree of flexibility in the course, and at the same time provide for an adequate coverage of basic areas, the content of the p
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optional areas.
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The guide b
frame of referenc

Core Area

Area I Similarit
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Area II Preparat
and Separation
Substances
Area III Structu
and Properties
Simple Organic
Compounds

Evaluation-Labora

OVERVIEW

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content of the proposed syllabus has been divided into three basic core areas and five optional areas. The minimum requirements of the course include the basic core (Areas I, II, and III) and any *two* of the optional areas. In addition, provision must be made at the local level to evaluate proficiency in laboratory skills. (See under "Final Examination.")

The guide below may help to establish a basic frame of reference for the course:

Core Area	Optional Areas (2 are required)	Suggested Time Allotment
Area I Similarities and Dissimilarities of Matter		9 weeks
Area II Preparation and Separation of Substances		10 weeks
Area III Structure and Properties of Simple Organic Compounds		2 weeks
	Area IV Further Study of Organic Compounds	6 weeks
	Area V Chemistry in the Home	6 weeks
	Area VI Water and Air Pollution	6 weeks
	Area VII Some Modern Materials and their Uses	6 weeks
	Area VIII Chemical Analysis	6 weeks
Evaluation-Laboratory Skills		1 week

Final examination

A final examination will be prepared by the Department for optional use by the local school system.

The final examination based on the course will consist of:

60 points (Basic core - Areas I, II, and III. Required by all.)
30 points (Fifteen points based on *each* optional area. Pupils must select *two* of the five areas.)
10 points (A laboratory-centered activity developed at the local level.) Teachers should complete this part of the evaluation before the date of the written examination.

Feedback necessary for the preparation and improvement of the examination will require random sampling of the General Chemistry answer sheets. Schools using the final examination should be prepared, upon request, to send the completed answer sheets to the Department for an item analysis.

The minimum time required for this course is five 45-minute periods per week. The course should be taught in a laboratory-classroom suitable for chemistry instruction, and *the laboratory approach to instruction should be used whenever possible.* It is recommended that pupils engage in laboratory-type activity an average of *three* periods per week.

Prerequisites

The successful completion of Ninth Year Mathematics, Course I - Algebra, is a prerequisite for this course in chemistry.

Organization of syllabus

The material in the syllabus is organized under four headings:

Topical Outlin
of topics
Understanding
the basic
course.
Laboratory Exp
suggestion
activities
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1. "A" followe
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For example
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2. "J" followe
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Supplementary I
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Appendix A - a listi
Appendix B - a bibli
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Appendix C - a listi

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Topical Outline - This column contains a listing of topics for quick reference by the teacher.

Understanding and Concepts - This column outlines the basic concepts to be introduced in the course.

Laboratory Experiences - This column contains suggestions and references for laboratory activities to be used in the course. These are coded to enable the teacher to locate them readily. Specific references by code are made to this publication, the *Science 7-8-9, Block J, The Chemistry of Matter,* and to the *Chemistry Handbook.*

The coding is as follows:

1. "A" followed by three digits indicates activities in Appendix A of this publication. For example, A 1.03 refers to the third activity in Area I.
2. "J" followed by one or two digits indicates the activity in the Appendix of *Science 7-8-9, Block J.*
3. "CH" followed by three digits indicates the activity in the *Chemistry Handbook.*

Supplementary Information - This column includes amplification and explanations of the basic concepts with examples to illustrate the depth of treatment intended. Material in this column will be subject to examination unless otherwise stated. Statements which delimit the material subject to examination, and specific suggestions to teachers are printed in italics in this column.

Cautions referring to laboratory activities are boxed in this column.

Appendix A - a listing of laboratory activities
Appendix B - a bibliography of chemistry reference materials
Appendix C - a listing of films and filmstrips

TOPICAL OUTLINE

AREA 1 - SIMILARITIES AND DISSIMILARITIES OF MATTER

- I. Substances
- II. Similarities and Dissimilarities Among Substances
  - A. Phase
    - 1. Gases
    - 2. Liquids
    - 3. Solids
    - 4. Change of phase
  - B. Density
  - C. Solubility
  - D. Other properties
    - 1. Luster
    - 2. Malleability
    - 3. Ductility
    - 4. Tenacity
    - 5. Brittleness
    - 6. Electrical conductivity
- III. Classes of Matter
  - A. Elements
    - 1. Metals
    - 2. Nonmetals
    - 3. Metalloids
  - B. Compounds
    - 1. Acids
    - 2. Bases
    - 3. Salts
    - 4. Organic compounds
  - C. Mixtures
    - 1. Suspensions
    - 2. Solutions
    - 3. Colloidal suspensions (colloids)
- IV. Reasons for Similarities and Dissimilarities
  - A. Atomic structure
    - 1. Protons
    - 2. Neutrons
    - 3. Electrons
  - B. Bond
    - 1. C
    - 2. I
- V. Periodi
  - A. Purp
  - B. Arra
  - C. Prop
    - 1. M
    - 2. N

AREA 2 - T

- I. Prepara
  - A. Ener
    - 1. A
    - 2. E
    - 3. E
    - 4. H
  - B. Type
    - 1. D
    - 2. E
    - 3. S
    - 4. D
    - 5. G
- II. Quantit
  - A. Mole
  - B. Chem
    - 1. S
    - 2. F
    - 3. E
  - C. Mass
    - 1. F
    - 2. F
    - 3. F
  - D. Volu
    - 1. M
    - 2. C

TOPICAL OUTLINE

S OF MATTER

g Substances

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larities

B. Bonding
    1. Covalent bonding
    2. Ionic bonding
V. Periodic Table
    A. Purpose
    B. Arrangement
    C. Properties
        1. Metals
        2. Nonmetals

AREA 2 - THE PREPARATION AND SEPARATION OF SUBSTANCES

I. Preparation of Substances
    A. Energy and reactions
        1. Activation energy
        2. Exothermic reactions
        3. Endothermic reactions
        4. Heat of formation
    B. Types of reactions
        1. Direct union or synthesis
        2. Exchange of ions
        3. Single replacement
        4. Decomposition
        5. Gain and loss of electrons
II. Quantitative Relationships
    A. Mole concept
    B. Chemical shorthand
        1. Symbols
        2. Formulas
        3. Equations
    C. Mass relationships
        1. From symbols
        2. From formulas
        3. From equations
    D. Volume relationships
        1. Mole volume
        2. Combining volumes

III. Preparation of Solutions
    A. Rate of dissolving
    B. Solubility
        1. Nature of solute and solvent
        2. Temperature
        3. Pressure
    C. Concentration
        1. Concentrated and dilute solutions
        2. Saturated, unsaturated, and supersaturated solutions
        3. Mass/volume
        4. Molarity
IV. Separation of Substances
    A. Separation by solubility
        1. Filtration
        2. Crystallization
    B. Separation by boiling points

AREA 3 - STRUCTURE AND PROPERTIES OF SIMPLE ORGANIC COMPOUNDS

I. Organic Compounds
    A. Definition
    B. General properties
II. Bonding in Organic Compounds
    A. Isomers
    B. Structural formulas
    C. Saturated and unsaturated compounds
    D. Homologous series
III. Some Classes of Organic Compounds
    A. Hydrocarbons
        1. Alkane series
        2. Unsaturated hydrocarbons
        3. Cyclic hydrocarbons
    B. Other organic compounds
        1. Alcohols
        2. Aldehydes
        3. Ketones
        4. Ethers
        5. Organic acids
        6. Esters
        7. Amine group
        8. Amino acids

AREA 4 - FURTHER STUDY OF ORGANIC COMPOUN

I. Hydrocarbons
    A. Series of hydrocarbons
        1. Alkanes
        2. Alkenes
        3. Alkynes
        4. Alkadienes
        5. Benzene series
    B. Reactions of hydrocarbons
        1. Substitution
        2. Addition
        3. Polymerization
        4. Cracking
II. Alcohols
    A. Classes of alcohols
    B. Properties of alcohols
    C. Some reactions of alcohols
        1. Oxidation
        2. Esterification
III. Aldehydes
IV. Organic Acids
V. Carbohydrates
    A. Monosaccharides
    B. Disaccharides
    C. Polysaccharides
VI. Proteins
    A. Formation from amino acids
    B. Hydrolysis
VII. Lipids

AREA 5 - CHEMISTRY IN THE HOME

I. Foods
    A. Preservation of foods
    B. Some food nutrients

        - 1. Carbohydrates
        - 2. Proteins
        - 3. Lipids
    - C. Changing structure of nutrients
        - 1. Hydrolysis
        - 2. Oxidation
        - 3. Coagulation
    - D. Changing texture or particle size
        - 1. Colloidal dispersions
        - 2. Forming gels
        - 3. Forming emulsions
        - 4. Leavening action
        - 5. Crystallization
- II. Home Cleaning and Sanitation
    - A. Soaps and detergents
        - 1. Soaps
        - 2. Detergents
    - B. Bleaching
    - C. Disinfectants

AREA 6 - ENVIRONMENTAL POLLUTION

- I. Introduction
- II. Water
    - A. Water supply
    - B. Naturally occurring substances in the water supply
        - 1. Rain water
        - 2. Ground water
    - C. Water pollutants
        - 1. Sewage
        - 2. Infectious agents
        - 3. Heat
        - 4. Sediments
        - 5. Radioactive substances
        - 6. Minerals and chemical substances
            - a. Plant nutrients
            - b. Pesticides
            - c. Industrial chemicals
            - d. Salt water
            - e. Detergents
            - f. Oil
    - D. Self-purification
        - 1. Degradation
        - 2. Decomposition
        - 3. Recovery
        - 4. Clean water
    - E. Water treatment
        - 1. Aeration
        - 2. Adsorption of gases
        - 3. Coagulation and sedimentation
        - 4. Chlorination
        - 5. Water softening
- III. Air
    - A. Composition of the air
    - B. Causes of air pollution
    - C. Some major air polluters
        - 1. Industry
        - 2. Internal combustion engines
        - 3. Furnaces and incinerators
    - D. Air pollutants
        - 1. Solids
        - 2. Liquids
        - 3. Gases
            - a. Carbon monoxide
            - b. Oxides of nitrogen
            - c. Gaseous sulfur compounds
            - d. Hydrocarbons
    - E. Prevention of air pollution
- IV. Land
    - A. Refuse disposal
        - 1. Open dumps
        - 2. Sanitary landfills
        - 3. Incineration
    - B. Prevention of land pollution

AREA 7 - SOME MODERN MATERIALS

- I. Polymers
    - A. Formation of polymers
        - 1. Condensation
        - 2. Addition

- B. Some representative polymers
  - 1. Polyamides
    - a. Proteins
    - b. Nylons
  - 2. Phenolic plastics
  - 3. Polyesters
  - 4. Vinyl plastics
  - 5. Silicones
    - a. Synthesis
    - b. Properties
- C. Some types of polymers
  - 1. Elastomers
  - 2. Fibers
  - 3. Thermoplastic polymers
  - 4. Thermosetting and cold-setting plastics

II. Industrial Metals
- A. "Natural" impurities
  - 1. Concentration of ore
  - 2. Reduction
- B. "Artificial" impurities - alloying
- C. Properties and uses of alloys

III. Radioisotopes
- A. Nature of radioactivity
  - 1. Stability of nuclei
  - 2. Nuclear energy
    - a. Fission reactors
    - b. Fusion reactors
  - 3. Major types of nuclear radiation
    - a. Alpha particles
    - b. Beta particles
    - c. Gamma rays
    - c. Neutrons
- B. Some properties and uses of radioisotopes
  - 1. Uses based on chemical reactivity
  - 2. Uses based on radioactivity
  - 3. Uses based on rate of decay and half-life
- C. Detection of nuclear radiation
  - 1. Film
  - 2. Electroscope
  - 3. Geiger counter
  - 4. Scintillation counter
- D. Radiation and human safety

AREA 8 - CHEMICAL ANALYSIS

I. Qualitative Analysis
- A. Precipitation
- B. Spectroscopy
- C. Chromatography
  - 1. Phases
  - 2. Rate of flow
  - 3. Identification
  - 4. Adsorption
  - 5. Thin layer
- D. Gas evolution

II. Quantitative Analysis
- A. Gravimetric methods
- B. Volumetric methods
  - 1. Gas measurement
  - 2. Titrating normal solutions
- C. Instrument analysis
  - 1. pH meters
  - 2. Colorimeters and spectrometers

Area 1 - Similarities and Dissimilar

Topical Outline	Understandings and Concepts	Laborato
I. Substances	A substance is a variety of matter, all specimens of which have identical properties and composition. A substance is homogeneous.	In all ar course, pu an increas of the con laboratory
II. Similarities and Dissimilarities Among Substances	Each substance has characteristic properties by which it can be recognized. Dissimilar substances may have some properties in common but will have some properties which differ. Some properties that may be used in classifying and identifying substances are color, luster, odor, density, phase at room temperature, melting	Laboratory should enab sort out an number of s the basis o ties and on obtained fr charts in t *Tables, Che* and textboo

a 1 - Similarities and Dissimilarities of Matter

Understandings and Concepts	Laboratory Experiences	Supplementary Information
		Material in this column will be subject to examination unless otherwise stated.
stance is a variety tter, all specimens ich have identical rties and composi- stance is homoge-	In all areas of this course, pupils should gain an increased understanding of the concepts through laboratory experience.	*The concepts shown in column II at the left for this area should have been covered to some extent in earlier science courses. Teachers should become acquainted with Science 7-8-9, Block J, The Chemistry of Matter, and review pertinent material with pupils when necessary.*
substance has charac- tic properties by it can be recog- . milar substances may some properties in n but will have some rties which differ. properties that may ed in classifying dentifying substances olor, luster, odor, ty, phase at room rature, melting	Laboratory experiences should enable pupils to sort out and classify a number of substances on the basis of their properties and on information obtained from tables and charts in the *Reference Tables*, *Chemistry Handbook*, and textbooks.	Some properties which can be determined *by the use of tables* are density, melting point, boiling point, solubility, and phase at room temperature. *For purposes of examination, pupils will be held responsible for the definitions and interpretation from tables and charts for density, melting point, boiling point, solubility, and phase.*

Topical Outline	Understandings and Concepts	Laboratory
	point, boiling point, hardness, brittleness, ductility, malleability, tenacity, electrical conductivity, and solubility.	
A. Phase	The term "phase" is used to refer to the gas, liquid, or solid form of matter. The phase in which matter exists depends on the attractive forces between its particles.	
1. Gases	Gases have neither a definite shape nor a definite volume. They assume the shape and volume of the container.	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
t, boiling point, ness, brittleness, ility, malleability, city, electrical con- ivity, and solubility.		*Pupils are not expected to memorize tables of physical constants.*
erm "phase" is used efer to the gas, id, or solid form of er.		The magnitude of the attractive forces between the particles of a substance increases as the distance between the particles decreases.
hase in which matter s depends on the active forces between articles.		The effectiveness of the attractive forces in holding the particles of a substance together depends on the magnitude of the forces and on the kinetic energy of the particles. The greater the kinetic energy of the particles, the greater the force required to hold them together.
		The kinetic energy of the particles of a substance increases with increasing temperature.
have neither a def- shape nor a definite me. They assume the and volume of the iner.		The particles of a substance in the gaseous phase are relatively far apart (as shown by the compressibility of gases)

Topical Outline	Understandings and Concepts	Laboratory Experier
2. Liquids	A liquid has a definite volume, but takes the shape of the container.	Pour liquids into co ers of various shape
3. Solids	A solid has a definite shape and volume.	Find the volume of r larly shaped objects using linear measure

Understandings and Concepts	Laboratory Experiences	Supplementary Information
		and the attractive forces have little effect on their behavior.
		In the gaseous phase the particles are moving faster (have more kinetic energy) than when the substance is in the liquid or solid phase.
uid has a definite e, but takes the of the container.	Pour liquids into containers of various shapes.	The particles in a liquid are relatively close together (as shown by the fact that liquids are not easily compressed). The particles are moving more slowly than in the corresponding gaseous phase, but more rapidly than when the substance is in the solid phase.
		The attractive forces are sufficiently strong to hold the particles together, but not strong enough to hold the particles in a fixed position relative to other particles.
d has a definite and volume.	Find the volume of regularly shaped objects by using linear measurements.	In the solid phase the attractive forces are sufficiently strong to hold

Topical Outline	Understandings and Concepts	Laboratory Experiences
	The particles of a solid resist a change of position.	The volume of an irregularly shaped object can be measured by finding t volume of water displace by the object.
4. Change of phase	Change of phase of a substance is accompanied by the absorption or release of heat.	A 1.01 in the appendix c be used to show changes between liquid and gasec phases.
	Energy is absorbed when a solid becomes a liquid and when a liquid becomes a gas.	The melting and freezing water or of a low meltin point substance such as naphthalene or paradichl obenzene can be used to illustrate the change between solid and liquid phases.
	Energy is released when a gas condenses to a liquid and when a liquid becomes a solid.	

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Laboratory Experiences

The volume of an irregularly shaped object can be measured by finding the volume of water displaced by the object.

A 1.01 in the appendix can be used to show changes between liquid and gaseous phases.

The melting and freezing of water or of a low melting point substance such as naphthalene or paradichlorobenzene can be used to illustrate the change between solid and liquid phases.

Supplementary Information

the particles in a regular geometric pattern. All true solids have a crystalline structure.

The energy absorbed or released during a change of phase represents a change in potential energy. Thus the energy absorbed when a solid changes to a liquid or a liquid to a gas does work in separating the particles, resulting in a higher potential energy content. For example, steam can cause more serious burns than boiling water at the same temperature because of its greater heat content.

During a change of phase, the energy absorbed or released does not affect the speed (therefore the kinetic energy) of the particles. Thus, there is no temperature change during a phase change.

Topical Outline	Understandings and Concepts	Laborat
a. Melting point	A pure solid has a definite temperature, called the melting point, at which it turns into a liquid.	Determin of a sol Directio melting found in manuals.
	A liquid changes into a solid at a temperature called its freezing point.	See CH 8 compariso point of
	The melting and freezing points are the same temperature for the same substance.	
	It is possible for a substance to exist as a solid and a liquid at the same temperature.	
b. Evaporation	Evaporation occurs whenever a liquid substance changes to a gas.	
	Evaporation tends to take place at all temperatures.	
	Evaporation rate is affected by temperature.	
	In a closed system, the vapor (gas) produced exerts a pressure which increases as the temperature of the liquid is raised.	

tandings oncepts	Laboratory Experiences	Supplementary Information
d has a defi- ature, called point, at rns into a	Determine the melting point of a solid such as ice. Directions for determining melting points can be found in most laboratory manuals.	The melting points and/or boiling points of substances can be found in reference tables, textbooks, and handbooks of chemistry.
anges into a temperature freezing point.	See CH 8.06 b, c, for a comparison of the melting point of two metals.	
and freezing the same tem- r the same sub-		
ble for a sub- xist as a liquid at the ature.		
occurs when- id substance a gas.		
tends to take l temperatures.		
rate is temperature.		
system, the produced essure which s the tempera- liquid is		The term "vapor" is frequently used to refer to the gas phase of a substance that is normally a liquid or a solid at room temperature.

Topical Outline	Understandings and Concepts	Laboratory Experien
	This vapor pressure is specific for each substance.	
c. Boiling point	A liquid will boil at a temperature at which the vapor pressure equals the pressure on the liquid. The normal boiling point is the temperature at which the vapor pressure of the liquid equals one atmosphere (760 mm. of mercury).	Measure the boiling of water. Air press and accuracy of the mometer may account possible differences readings.
B. Density	Density is the mass per unit volume of a substance.	Density can easily b determined in the lab tory. A variety of of determining densi are given in most la tory manuals or high school physics textb

erstandings Concepts	Laboratory Experiences	Supplementary Information
r pressure is for each sub-		
will boil at a re at which the ssure equals the on the liquid.	Measure the boiling point of water. Air pressure and accuracy of the thermometer may account for possible differences in readings.	"Boiling point is the temperature at which a liquid changes to a gas" is an inaccurate definition often used. A liquid will change to a gas at any temperature. The boiling point depends on the pressure on the liquid.
l boiling point mperature at vapor pressure quid equals one e (760 mm. of		Autoclaves used for sterilizing materials and pressure cookers operate on the principle that the boiling point is increased when the pressure on the liquid is increased. Figures given for boiling points of liquids in reference tables are "normal boiling points."
s the mass per me of a substance.	Density can easily be determined in the laboratory. A variety of ways of determining density are given in most laboratory manuals or high school physics textbooks.	Density should be expressed in metric (cgs) units. The density of solids and liquids is usually expressed in grams per milliliter (g/ml.). The density of gases is

Topical Outline	Understandings and Concepts	Laboratory Ex
	When the density of a substance is compared with the density of water, the resulting value is called the specific gravity.	The specific g various liquid determined in tory using hyd
C. Solubility	Solubility is the ability to dissolve in another substance called a solvent.	Compare the am undissolved so after equal qu different solu been added to umes of water.
D. Other properties		
1. Luster	The silvery shine of many substances is called luster.	See CH 8.02 fo activities dea luster. Sandpaper dull observe their

dings epts	Laboratory Experiences	Supplementary Information
		usually expressed in grams per liter.
		The density of water is considered to be 1 g/ml.
ty of a sub- ared with water, the e is called ravity.	The specific gravity of various liquids can be determined in the laboratory using hydrometers.	Density = sp.gr. x 1 g/ml. In the metric system, specific gravity and density have the same numerical value. Specific gravity is also known as relative density.
the ability another ed a sol-	Compare the amounts of undissolved solid left after equal quantities of different solutes have been added to equal volumes of water.	*Pupils should have studied the property of solubility in Section V-B-2 of Block J (pp. 60-63).* *Further details on solutions will be studied in Section III C of this Area and in Area 2.*
ine of many called lus-	See CH 8.02 for suggested activities dealing with luster. Sandpaper dull metals to observe their luster.	*Pupils should have some firsthand experience with the properties of luster, malleability, ductility, tenacity, brittleness, and electrical conductivity.*

Topical Outline	Understandings and Concepts	Laboratory E
2. Malleability	Malleability is the ability to be pounded into thin sheets.	Zinc and copp be hammered o new shapes.
3. Ductility	Ductility is the ability to be drawn into a wire.	Experiments i tility are be of this cours pupils can in of different composition t the term.
4. Tenacity	Tenacity (tensile strength) is the ability to resist being pulled apart.	Activity J-15 the differenc strength betw metals. The can be used t tensile stren ent fibers.
5. Brittleness	Brittleness is the tendency to shatter when struck with a sharp blow.	Compare the b sulfur with 1 by hitting a with a hammer
6. Electrical conductivity	Electrical conductivity is the ability of a substance to pass an electric current.	See CH 8.04 a for activitie trate electri tivity.

rstandings Concepts	Laboratory Experiences	Supplementary Information
ity is the o be pounded into ts.	Zinc and copper sheets can be hammered or worked into new shapes.	
is the ability wn into a wire.	Experiments involving ductility are beyond the scope of this course. However, pupils can inspect wires of different gauges and composition to understand the term.	
(tensile strength) ility to resist led apart.	Activity J-15 illustrates the difference in tensile strength between two metals. The same method can be used to compare the tensile strength of different fibers.	
ss is the tendency r when struck with low.	Compare the brittleness of sulfur with lead or copper by hitting a piece of each with a hammer.	There are several other properties, such as fracture, streak, cleavage, and hardness which pupils may have encountered in earth science courses.
l conductivity is ty of a substance n electric cur-	See CH 8.04 a(1) and b for activities to illustrate electrical conductivity.	

Topical Outline	Understandings and Concepts	Laboratory Experi
III. Classes of Matter		
A. Elements	An element is a substance which cannot be decomposed by a chemical change.	A collection of el can be sorted int or nonmetal group basis of luster a ductivity.
1. Metals	The majority of the elements are metals; they have luster, are malleable and ductile, and are good conductors of heat and electricity.	
	All metals except mercury are solids at room temperature.	
2. Nonmetals	Nonmetals, except bromine, are gases or brittle solids; they lack luster and are poor conductors of heat and electricity.	
3. Metalloids	Metalloids are those elements which have certain properties characteristic of metals and other properties characteristic of nonmetals.	

derstandings nd Concepts	Laboratory Experiences	Supplementary Information
ment is a substance cannot be decomposed hemical change.	A collection of elements can be sorted into metal or nonmetal groups on the basis of luster and conductivity.	*Teachers may wish to introduce the symbols of some of the common elements at this point. Review the use of symbols as covered in Section IV of* *Block J*.
ority of the ele- re metals; they ster, are malleable tile, and are good tors of heat and icity.		*The quantitative significance of symbols will be treated in Area 2, Section II C.* *Atomic structure is treated in Section IV of this Area.*
tals except mercury lids at room tem- re.		
als, except bromine, ses or brittle ; they lack luster e poor conductors t and electricity.		Many nonmetals can cause skin burns or are poisonous.
oids are those ele- which have certain ties characteristic als and other prop- characteristic of als.		Examples of metalloids are boron, silicon, arsenic, and tellurium.

Topical Outline	Understandings and Concepts	Laborat
B. Compounds	A compound is a substance which can be decomposed by a chemical change. A compound is composed of two or more elements chemically united. All samples of a compound have identical composition and properties. The components of a compound are present in a definite mass ratio which cannot be varied. Compounds may be classified according to their structure, composition, or properties.	Heating burning activiti used for the defi *do not s* *magnesiu*
1. Acids	The properties of a compound may be used to classify it as an acid:	The chemi contains concernin
	. An acid is a compound which produces hydrogen ions when dissolved in water.	CH 5.14 CH 5.15 -
	. Acids affect the color of acid-base indicators.	CH 5.16 -
	. Acids neutralize the effect of bases.	CH 5.17 -
	. Acids react with many metals to liberate hydrogen gas.	CH 5.18 -

Understandings and Concepts	Laboratory Experiences	Supplementary Information
ompound is a substance ch can be decomposed a chemical change. A pound is composed of or more elements chem- lly united.	Heating mercuric oxide and burning magnesium are activities which can be used for understanding of the definition. *Caution: do not stare at burning magnesium.*	The decomposition of mercuric oxide should be carried out in a fume hood, preferably as a teacher demonstration. Both mercury and mercury vapor are extremely toxic. Pupils should not be allowed to handle mercury.
samples of a compound e identical composition properties.		
components of a com- nd are present in a inite mass ratio which not be varied.		
pounds may be classi- d according to their ucture, composition, or perties.		The classification of compounds greatly simplifies the study of chemistry.
properties of a com- nd may be used to ssify it as an acid: n acid is a compound hich produces hydrogen ons when dissolved in ater. cids affect the color f acid-base indicators. cids neutralize the ffect of bases. cids react with many etals to liberate ydrogen gas.	The chemistry handbook contains several activities concerning pH. CH 5.14 - pH of distilled water CH 5.15 - Preparation of solutions of known pH CH 5.16 - Color change of indicators CH 5.17 - pH of some common substances CH 5.18 - Neutralization	Acids can be defined in a number of ways. *Pupils should be familiar with the pH scale and should understand that each whole number on the scale represents a difference of 10 times in the concentration of hydrogen ions per liter of solution.* *Pupils are not expected to know that the pH number is the logarithm of the reciprocal of the hydrogen ion concentration.*

Topical Outline	Understandings and Concepts	Laboratory Exp
	. Acids have a sour taste. The sour taste of many foods is due to the presence of naturally-occurring acids. . Acids react with carbonates to liberate carbon dioxide gas.	
2. Bases	The properties of a compound may be used to classify it as a base: . Bases affect the color of acid-base indicators. . The solution of a base feels slippery. . Bases neutralize the effect of acids.	Properties of ba shown by use of and 5.12.
3. Salts	A salt can be considered as a product of the neutralizing of an acid with a base. Most salt compounds are found in the minerals of the earth and in sea water, or are produced by other chemical reactions.	Compare the color bility of several

	Laboratory Experiences	Supplementary Information
taste. many he ally-		Pupils should not be allowed to taste laboratory acids or other chemicals.
carbon- carbon		Pupils should be warned that strong acid solutions are caustic to the skin.
a com- to ase: color icators. a base e the .	Properties of bases may be shown by use of CH 5.11 b and 5.12.	*Bases can also be defined in a number of ways. In this syllabus only a definition based on the properties of bases will be required.* Pupils should be warned that strong basic solutions are caustic to the skin.
idered as eutraliz- h a base. ls are als of ea water, other s.	Compare the color and solubility of several salts.	Although salts have a salty taste, many of them are poisonous, so the property should not be tested.

Topical Outline	Understandings and Concepts	Laboratory Experie
	The properties of salts vary widely.	
4. Organic compounds	Organic compounds are compounds of carbon.	
C. Mixtures	A mixture consists of two or more distinct substances differing in properties and composition.	The separation of m can provide experie numerous techniques mixture of salt, pr tated chalk, sand, iron filings might
	The composition of a mixture can be varied.	
	Mixtures may be homogeneous (e.g., solutions or mixtures of gases) or heterogeneous (e.g., a mixture of iron and sulfur).	Microscopic study o from a river bed wi some interesting co nents.
1. Suspensions	Suspensions are mixtures containing particles of one substance (usually a solid) suspended in another substance (usually a liquid).	

standings Concepts	Laboratory Experiences	Supplementary Information
ties of salts y.		
mpounds are com- carbon.		There are other definitions of organic compounds which will not be used in this course. *Organic compounds are treated more fully in Area 3 and optional Area 4.*
consists of two stinct sub- ffering in prop- composition. ition of a mix- e varied.	The separation of mixtures can provide experience in numerous techniques. A mixture of salt, precipitated chalk, sand, and iron filings might be used.	In a mixture, as opposed to a compound, the components retain their own properties.
ay be homoge- ., solutions or f gases) or ous (e.g., a iron and sul-	Microscopic study of sand from a river bed will show some interesting components.	
s are mixtures particles of nce (usually a ended in stance (usually		Suspensions are opaque to the passage of light. The particles are visible and can be removed by filtration.

Topical Outline	Understandings and Concepts	Laboratory Ex
	A suspension can be made in varying proportions.	
2. Solutions	A solution is a homogeneous mixture.	
	A solution can be made in varying proportions.	
a. Solute	The solute is the substance which is dissolved.	
	Solutes vary in their solubility.	
b. Solvent	A solvent is the dissolving substance.	

rstandings Concepts	Laboratory Experiences	Supplementary Information
ion can be made proportions.		
is a homoge- ure.		*Material on solutions should have been covered in* *Block J* *and only a brief review should be necessary.*
can be made in oportions.		
		The dissolved particles in a solution are not visible, do not interfere with the passage of light, do not settle out on standing, and cannot be removed by filtration.
is the sub- h is dissolved.		The solute may be a solid, a liquid, or a gas.
y in their		In a strict sense, no substance is absolutely insoluble.
the dis- stance.		The solvent may be a solid, a liquid, or a gas.
		The most common solutions are those in which the solvent is a liquid. Solutions referred to in this syllabus are understood to be solutions in liquid solvents unless otherwise specified.

Topical Outline	Understandings and Concepts	Laboratory Experie
	Solvents vary in their ability to dissolve solutes.	
	Water is the most common solvent.	
	Tinctures are solutions in which ethanol is used as a solvent.	The difference in s ity of iodine in wa in ethanol can be d strated.
3. Colloidal suspensions (colloids)	A colloid is a mixture containing particles which are larger than those in a solution but smaller than those in a suspension.	See CH 3.46 for the aration of a colloi
	Colloids have some properties of a solution and some properties of a suspension.	
	Colloidal suspensions show the Tyndall effect.	The Tyndall effect demonstrated by the CH 3.53.
a. Dispersing medium	The medium in which the colloidal particles are suspended is known as the dispersing medium.	

tandings oncepts	Laboratory Experiences	Supplementary Information
ry in their dissolve sol-		*Factors affecting solubility and methods of expressing concentrations of solutions are treated in Area 2.*
e most common		
re solutions in ol is used as	The difference in solubility of iodine in water and in ethanol can be demonstrated.	
s a mixture particles which than those in a t smaller than suspension.	See CH 3.46 for the preparation of a colloid.	
ve some proper- olution and ties of a sus-		
uspensions show effect.	The Tyndall effect can be demonstrated by the use of CH 3.53.	Colloidal particles do interfere with the passage of light.
in which the articles are s known as the medium.		

Topical Outline	Understandings and Concepts	Laborator
b. Dispersed substance	The suspended colloidal particles form the dispersed substance.	
IV. Reasons for Similarities and Dissimilarities		
A. Atomic structure	An atom is the smallest particle of an element that can exist separately or enter into combination with other atoms. All atoms of the same element are chemically alike. Atoms of different elements are chemically different. The atomic mass of an atom is the relative mass in comparison to the mass of the carbon-12 atom, which is assigned an arbitrary value of exactly 12 units, called atomic mass units. An atom is composed of protons, neutrons, and electrons. The protons and neutrons are concentrated in the central part of the atom called the nucleus. Col-	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
suspended colloidal icles form the dis- ed substance.		
tom is the smallest icle of an element can exist separately nter into combination other atoms.		*This material is treated in Sections III a-III B2c of Block J, and only a brief review should be necessary.*
atoms of the same ele- are chemically alike.		
s of different elements chemically different.		
atomic mass of an atom e relative mass in arison to the mass of carbon-12 atom, which ssigned an arbitrary e of exactly 12 units, ed atomic mass units.		An atomic mass unit (amu) is defined to be 1/12 the mass of the carbon-12 atom.
tom is composed of ons, neutrons, and trons.		The common isotope of hydrogen contains no neutrons.
protons and neutrons concentrated in the ral part of the atom ed the nucleus. Col-		*Although protons and neutrons are the only nuclear particles that have been identified in an intact*

Topical Outline	Understandings and Concepts	Laboratory E
	lectively they are called nucleons.	
	An atom consists of a nucleus in association with one or more electrons.	
	For most practical purposes, the entire mass of an atom may be considered to be in the nucleus.	
	Electrons are located outside the nucleus and are distributed in the space which makes up most of the atom.	
1. Protons		
a. Charge	A proton has a single positive charge.	Electrical ch demonstrated rubber or gla an electrosco from the phys tory.

Laboratory Experiences

Electrical charges can be demonstrated with charged rubber or glass rods and an electroscope borrowed from the physics laboratory.

Supplementary Information

nucleus, other particles have been identified among the break-down products of certain nuclear disintegrations. The relationship of these particles to the structure and stability of the nucleus is the subject of much current research and is beyond the scope of this course.

Topical Outline	Understandings and Concepts	Laboratory Experi
b. Mass	A proton has a mass of approximately one atomic mass unit.	
c. Symbol	The symbols used to represent a proton are p, and $^{1}_{1}H$.	
d. Atomic number	The atomic number indicates the number of protons in the nucleus of an atom.	
	All atoms of the same element contain the same number of protons, and hence have the same atomic number.	
	Atoms do not gain or lose protons in any chemical reaction.	
2. Neutrons		
a. Charge	The neutron has no electrical charge.	
b. Mass	The neutron has a mass similar to that of the proton.	

ings pts	Laboratory Experiences	Supplementary Information
mass of ne atomic		The actual mass of the proton is 1.007267 atomic mass units.
l to rep- are p, and		
er indicates rotons in an atom.		The atomic number may be indicated by a subscript number placed on the left of the symbol, e.g., $_{6}C$.
e same ele- e same num- and hence tomic num-		The atomic number identifies the element.
in or lose chemical		
no elec-		
a mass of the pro-		The actual mass of the neutron is 1.008665 atomic mass units; that of the proton is 1.007267 amu.

Topical Outline	Understandings and Concepts	Laboratory E
c. Symbol	A symbol often used for a neutron is n, or ^1_0n.	
d. Mass number	The mass number of an atom is the total of the number of protons and neutrons in the nucleus.	
e. Number of neutrons	The number of neutrons in a nucleus can be found by subtracting the atomic number from the mass number of the atom.	
f. Isotopes	Isotopes are atoms of the same element (therefore having the same number of protons) which differ in the number of neutrons.	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
A symbol often used for a neutron is n, or $^{1}_{0}n$.		
The mass number of an atom is the total of the number of protons and neutrons in the nucleus.		The mass number may be indicated by a superscript number placed on the left of the symbol, e.g., ^{12}C. Distinguish between mass number and atomic mass. The mass number indicates the total of the number of protons and neutrons of an atom and is always a whole number. The atomic mass of an element is the weighted average mass of the naturally occurring isotopes of that element and is usually a fractional number.
The number of neutrons in a nucleus can be found by subtracting the atomic number from the mass number of the atom.		
Isotopes are atoms of the same element (therefore having the same number of protons) which differ in the number of neutrons.		Isotopes are usually named by affixing the mass number to the name of the element, as carbon-12. An exception is frequently made in naming the three isotopes of hydrogen. The most abundant isotope $^{1}_{1}H$, is usually referred to as hydrogen, but has been

Topical Outline	Understandings and Concepts	Laboratory Experie
	Isotopes of the same element are chemically the same, but differ in mass.	
3. Electrons		
a. Charge	The electron has a single negative charge.	
b. Mass	The mass of an electron is 1/1836 that of a proton. Electrons do not contribute significantly to the total mass of the atom.	
c. Symbol	The symbols used to represent an electron are e^- and ${}^{0}_{-1}e$.	
d. Number of electrons	In any neutral atom there are the same number of electrons as protons.	

Laboratory Experiences

Supplementary Information

called "protium." The isotope $^{2}_{1}H$, is frequently called "deuterium," and $^{3}_{1}H$ is called "tritium."

The atomic mass of an element, as given in atomic "weight" tables, is the average mass of the naturally occurring isotopes of the element.

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Topical Outline	Understandings and Concepts	Laboratory
e. Energy levels	The electrons are outside the nucleus at various energy levels.	
	In the Bohr model of the atom, electrons are considered to revolve around the nucleus in one of several concentric circular orbits.	Activities f models of at may be foun 2.08 and in
	The orbits are called shells, rings, or principal energy levels and can be denoted by the letters K, L, M, N, O, P, Q, or by the numbers 1, 2, 3, 4, 5, 6, 7.	
	Electrons in orbits near the nucleus have less energy than those in orbits farther from the nucleus.	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
e electrons are outside e nucleus at various ergy levels.		
the Bohr model of the om, electrons are con- dered to revolve around e nucleus in one of sev- al concentric circular bits.	Activities for illustrating models of atomic structure may be found in CH 2.07-2.08 and in J-25.	*Teachers should stress that the Bohr model is one of several models used to explain the behavior of atoms which are too small to be seen or isolated. A model represents an approximation of atomic structure and does* **not** *picture the actual atom.*
e orbits are called ells, rings, or princi- l energy levels and can denoted by the letters L, M, N, O, P, Q, or by e numbers 1, 2, 3, 4, 5, 7.		
ectrons in orbits near e nucleus have less ergy than those in orbits rther from the nucleus.		It should be pointed out that the electrons do not actually travel in regular circular orbits. Their actual motion more closely resembles the random motion of bees around a hive. However, the principal energy level or shell represents the energy associated with a definite **average** distance from the nucleus.

Topical Outline	Understandings and Concepts	Laboratory
f. Electron distribution	There is a maximum number of electrons which each orbit can hold.	
	The first (K) energy level can hold no more than 2 electrons.	
	The second (L) energy level can hold no more than 8 electrons.	
	Atoms with atomic numbers 1-20 can have no more than 8 electrons in the third (M) energy level.	
g. Excited atoms - spectral lines	When atoms absorb energy, electrons may shift to higher energy levels. The atom is then said to be in the excited state.	
	The excited state is unstable, and the electrons fall back to a lower energy level.	
	When elements are sufficiently excited in the vapor phase, they yield radiant energy in the form	CH 2.17 is dealing wit lines.

erstandings nd Concepts	Laboratory Experiences	Supplementary Information
a maximum number trons which each n hold.		*Pupils should be able to use the Bohr model to represent the probable structure of atoms and ions and to indicate electric charge.*
t (K) energy level no more than 2 s.		
nd (L) energy level no more than 8 s.		*For purposes of examination, models will be limited to the first 20 elements, and the necessary information may be obtained from Reference Tables.*
th atomic numbers have no more than ons in the third gy level.		Representations of atoms with numbers greater than 20 are complicated by exceptions to the simple rules stated.
ms absorb energy, s may shift to nergy levels. The then said to be in ted state.		
ted state is unsta- the electrons fall a lower energy		
ments are suffi- excited in the ase, they yield energy in the form	CH 2.17 is an activity dealing with spectral lines.	The use of spectroscopy in identifying elements is treated in optional Area 8.

Topical Outline	Understandings and Concepts	Laboratory Exp
	of characteristic spectral lines which can identify the element.	
h. Valence electrons	The electrons in the outermost shell of an atom are called the valence electrons.	
	The valence shell of an atom is complete with 8 electrons. (The K-shell, which is complete with 2 electrons, is an exception.)	
	The chemical behavior of an element depends largely on the number of valence electrons.	
B. Bonding	Atoms with incomplete valence shells tend to combine with other atoms to complete their valence shells.	
	Atoms may achieve a complete valence shell by losing, gaining, or sharing electrons.	
	The number of electrons transferred or shared between atoms is such that each atom acquires a	Pupils can use board or other rial to show ho can be transfer

gs s	Laboratory Experiences	Supplementary Information
spectral dentify		
the out- n atom are e elec-		
of an with 8 K-shell, e with 2 excep-		Stress the peculiar stability of a complete valence shell.
avior of ds largely valence		
nplete tend to com- atoms to valence		
ve a com- hell by , or shar-		
electrons shared is such that ires a	Pupils can use the felt board or other model material to show how electrons can be transferred to form	The number of electrons transferred or shared between atoms in forming compounds determines the

Topical Outline	Understandings and Concepts	Laboratory E
	complete valence shell.	compounds and "transfer numb dation number Directions fo ing a felt boa on p. 354 of t *Handbook*.
	Elements may be classified according to their tendency to lose, gain, or share electrons in combining with other elements.	
	Metals tend to lose electrons when combining with other elements.	
	In general, atoms with 1, 2, or 3 valence electrons tend to lose electrons and are classified as metals.	
	When an atom loses electrons, the resulting particle is no longer electrically neutral but has an excess positive charge. Such a particle is called a positive ion.	CH 8.08 shows t form positive i

derstandings nd Concepts	Laboratory Experiences	Supplementary Information
e valence shell.	compounds and relate the "transfer number" to oxidation number values. Directions for constructing a felt board are found on p. 354 of the *Chemistry Handbook*.	oxidation state of the atoms in the compound. Have pupils refer to the oxidation states listed in the *Reference Tables*.
s may be classified ng to their ten- o lose, gain, or lectrons in combin- h other elements.		*Teachers should introduce formula writing at this point. Review the writing of formulas as covered in Section IV of Block J.*
tend to lose elec- hen combining with lements.		*The quantitative significance of formulas will be treated in Area 2, Section II C.*
ral, atoms with 1, 3 valence electrons lose electrons and ssified as metals.		
atom loses elec- the resulting par- is no longer elec- ly neutral but has ss positive charge. particle is called tive ion.	CH 8.08 shows that metals form positive ions.	The positive charge on a metal ion is equal to the number of electrons lost. Thus, sodium with one valence electron forms a +1 ion, and calcium with two valence electrons forms a +2 ion. The

Topical Outline	Understandings and Concepts	Laboratory Experie
	The relatively "free" electrons of metallic atoms account for several properties of metals such as electrical conductivity and luster.	
	Nonmetals tend to gain electrons when combining with metals or to share electrons when combining with other nonmetals.	Display a number of compounds labeled w their formulas. So compounds on the ba those containing on metals and both me

erstandings d Concepts	Laboratory Experiences	Supplementary Information
		oxidation number of a metal ion is equal to the charge on the ion.
tively "free" s of metallic count for several es of metals such rical conductiv- luster.		A metal consists of an arrangement of positive ions which are located at the crystal lattice sites and immersed in a "sea" of mobile electrons. These mobile electrons can be considered as belonging to the whole crystal rather than to individual atoms. As light strikes the surface of the metal, it affects the mobile electrons. The net result is that the electrons in "reflecting back" the light cause a lustrous appearance. The mobile electrons are responsible for the ability of the metallic solid to conduct electricity.
ls tend to gain ns when combining tals or to share ns when combining her nonmetals.	Display a number of binary compounds labeled with their formulas. Sort the compounds on the basis of those containing only nonmetals and both metals	

Topical Outline	Understandings and Concepts	Laboratory Exper
		and nonmetals.
	In general, atoms with 5, 6, or 7 valence electrons are classified as nonmetals. When a nonmetal atom gains electrons it becomes a negative ion.	Use the conductiv aqueous metallic tions to illustra presence of ions.
	Atoms with complete valence shells are classified as inert elements since they seldom enter into any chemical action.	Display neon, kry argon light bulbs color of the ligh by the bulb is on identifying the g Pupils who like t library research enjoy reading abo discovery of the gases.

Understandings and Concepts	Laboratory Experiences	Supplementary Information
	and nonmetals.	It is recommended that films be used to show reactions involving nonmetals other than oxygen. The poisonous nature of the elements or their products makes them generally unsuitable for pupil use in this course.
neral, atoms with 5, 7 valence electrons lassified as non- ls.	Use the conductivity of aqueous metallic salt solutions to illustrate the presence of ions.	
a nonmetal atom gains trons it becomes a tive ion.		The negative charge on a nonmetal ion is equal to the number of electrons gained. The oxidation number is equal to the charge on the ion.
s with complete valence ls are classified as t elements since they om enter into any ical action.	Display neon, krypton, and argon light bulbs. The color of the light emitted by the bulb is one way of identifying the gas. Pupils who like to do library research might enjoy reading about the discovery of the noble gases.	Other names for the inert gases are noble gases or rare gases. The term, *inert*, is no longer strictly applicable to these elements since it has been possible to form compounds of krypton, xenon, and radon with fluorine and oxygen. However, the term is still in

Topical Outline	Understandings and Concepts	Laboratory Exper
1. Covalent bonding	A covalent bond is formed when two atoms share electrons.	
	The number of electrons shared is such that each atom attains a complete valence shell.	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
		general use, and the electron configuration is quite generally referred to as the "inert gas structure."
ovalent bond is formed two atoms share elec- s.		The electrons shared in a covalent bond are considered as occupying the valence shells of both atoms.
number of electrons ed is such that each attains a complete nce shell.		Chlorine atoms, with 7 valence electrons, can complete their valence shells by sharing one pair of electrons with another atom; nitrogen atoms, with 5 valence electrons, must share 3 pairs of electrons in order to complete the valence shell.
		The oxidation numbers assigned to atoms sharing electrons are governed by arbitrary rules. *Pupils will not be required to learn these rules.* However, for purposes of formula writing the following generalizations are useful: (1) atoms of uncombined elements are assigned an oxidation number of 0; (2) in binary

Topical Outline	Understandings and Concepts	Laboratory E
a. Nonpolar bonds	When two atoms of the same element share electrons, the electrons are shared equally between the two atoms, forming a nonpolar covalent bond.	
b. Polar bonds	When two atoms of different elements share electrons, the shared electrons may be more strongly attracted to one of the atoms. As a result, one end of the bond may be somewhat more negative than the other. Such a bond is called a polar covalent bond.	

ndings cepts	Laboratory Experiences	Supplementary Information
		compounds of nonmetals, the oxidation number of each atom represents the number of shared electrons, with the more electronegative element assigned a negative oxidation number and the less electronegative element a positive oxidation number.
		Since oxygen is a strongly electronegative element (second only to fluorine), oxygen has an oxidation number of -2 in most oxides.
s of the share elec- ectrons are y between the rming a non- t bond.		Most uncombined nonmetallic elements achieve the stability of a complete valence shell by nonpolar covalent bonding.
s of different e electrons, ectrons may gly attracted atoms. As a nd of the omewhat more the other. s called a t bond.		The measure of the ability of an element to attract shared electrons is known as its electronegativity. *Pupils should be able to use an electronegativity table to predict the nature of a bond. Assume that an electronegativity difference of 1.7 or greater indicates an ionic bond.*

Topical Outline	Understandings and Concepts	Laboratory Exper
c. Molecules	A molecule may be defined as the smallest particle of any substance that can exist free and still exhibit all of the properties of the original substance.	
	When a molecule contains atoms of different elements, the number of each kind of atom is such that every atom attains a complete valence shell.	
	A molecule in which the electrons are evenly distributed is said to be a nonpolar molecule.	

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Supplementary Information

Nonmetallic elements that are gases at room temperature have diatomic molecules.

When carbon, needing 4 valence electrons, combines with hydrogen, needing 1 valence electron, one carbon atom can share one pair of electrons with each of four hydrogen atoms to form a molecule having the formula CH_4. When carbon combines with oxygen, which needs 2 valence electrons, one carbon atom can combine with two oxygen atoms to form a molecule having the formula CO_2.

A molecule may be nonpolar (1) if the bonds in the molecule are nonpolar, or (2) if the geometry of the molecule results in a symmetrical arrangement of polar bonds. A molecule of an element is nonpolar, since only nonpolar bonds are present; a molecule of methane, CH_4, is nonpolar

Topical Outline	Understandings and Concepts	Laboratory Experie
	A molecule in which the electron density is greater at one end of the molecule than the other is said to be a polar molecule, or a dipole.	
d. Forces between molecules	In general, the forces of attraction between molecules are weak forces.	
	The attractive forces between molecules increase as the size of the molecules increases.	
	The attractive forces between polar molecules are greater than between nonpolar molecules of comparable size.	
	The properties of covalent substances depend on the attractive forces between the individual	

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Laboratory Experiences

Supplementary Information

because of the symmetrical arrangement of the polar carbon-hydrogen bonds around the carbon atom.

A diatomic molecule composed of two unlike atoms is polar. For example, the hydrogen chloride molecule, HCl, is polar. Water is an example of a polar molecule containing more than two atoms.

While the covalent bonds holding the atoms together to form the molecule may be strong, the attractive forces between the molecules are relatively weak.

Topical Outline	Understandings and Concepts	Laboratory Experi
	molecules.	
e. Properties of covalent substances		
(1) Melting and boiling points	Covalent substances generally have low melting and boiling points.	Illustrate the low point of paraffin heating the wax on bath. Compare the with those obtaine an ionic substance heated in a simila
(2) Conductivity	Covalent substances generally are poor conductors of electricity.	Show that sulfur d have any mobile el or ions by using t ductivity test.
(3) Solubility	Nonpolar substances tend to dissolve in nonpolar solvents.	Compare the solubi of iodine and sodi chloride crystals water and nonpolar

derstandings nd Concepts	Laboratory Experiences	Supplementary Information
es.		
t substances gen- have low melting ling points.	Illustrate the low melting point of paraffin wax by heating the wax on a water bath. Compare the results with those obtained when an ionic substance is heated in a similar manner.	Covalent substances exist as gases, liquids, or low melting point solids at room temperature.
t substances gen- are poor conduc- electricity.	Show that sulfur does not have any mobile electrons or ions by using the conductivity test.	Covalent substances lack ions or mobile electrons needed to conduct electricity. The valence electrons are "tied up" in covalent bonds.
		It should be pointed out that acids in water solution react with water molecules to produce ions. Thus water solutions of acids will conduct an electrical current.
r substances tend solve in nonpolar s.	Compare the solubilities of iodine and sodium chloride crystals in polar water and nonpolar benzene.	Organic solvents in general are nonpolar.

Topical Outline	Understandings and Concepts	Laboratory Exper
	Polar substances tend to dissolve in polar solvents.	
2. Ionic bonding	When metal atoms, which lose electrons readily, react with nonmetal atoms with a strong tendency to gain electrons, the valence electrons of the metal atoms may be transferred completely to nonmetal atoms. The electrostatic attraction between the oppositely charged ions so formed is called an ionic bond.	
a. Structure of ionic compounds	The electrostatic forces between oppositely charged ions are sufficiently strong to hold the ions in relatively fixed sites, forming a crystal lattice.	Some pupils might build a styrofoam model of a sodium crystal. Directi be found in most manuals.

ings epts	Laboratory Experiences	Supplementary Information
		Benzene should be used only under the hood since its vapors are toxic and flammable.
es tend to ar solvents.		Water is the most common polar solvent. A general rule of solubility is "like dissolves like."
ns, which readily, etal atoms endency to the valence e metal ansferred onmetal ectrostatic een the ged ions so d an ionic		
ic forces ely charged iently the ions in d sites, al lattice.	Some pupils might like to build a styrofoam ball model of a sodium chloride crystal. Directions can be found in most laboratory manuals.	The salt cube model can be quickly drawn on the blackboard to illustrate lattice sites. In an ionic crystal there are no discrete neutral units that could be called molecules.

Topical Outline	Understandings and Concepts	Laboratory Experi
b. Properties of ionic compounds		
(1) Melting and boiling points	Ionic compounds have high melting and boiling points, and are solids at room temperature.	That sodium chlori other ionic crystal not be easily melte the laboratory is a rect indication of high melting and bo points.
(2) Conductivity	In the solid phase, ionic compounds are poor conductors of electricity. Electrical conductivity can occur only after the destruction of the lattice structure of an ionic solid and the release of the ions. Melting, and dissolving the crystal in water are ways of destroying the lattice structure.	Test the electrical ductivity of hypo (thiosulfate) crysta the solid, "melted, dissolved form. Wh the "melted form" i true liquid phase, be used as an analo compounds with melt points too high to obtained easily or in the laboratory.
(3) Solubility	In general, ionic compounds tend to dissolve in polar solvents and are insoluble in nonpolar solvents.	Use small round mag represent the "dipo action of water in thumbtack "ions" fr some prearranged or

erstandings d Concepts	Laboratory Experiences	Supplementary Information
mpounds have high and boiling and are solids at perature.	That sodium chloride and other ionic crystals cannot be easily melted in the laboratory is an indirect indication of their high melting and boiling points.	The high melting and boiling points of ionic compounds are due to the strength of the ionic bonds and the high energy required to permit ions to escape from the crystal lattice.
olid phase, ionic s are poor con- of electricity. al conductivity r only after the ion of the lattice e of an ionic d the release of . Melting, and ng the crystal in e ways of destroy- lattice structure.	Test the electrical conductivity of hypo (sodium thiosulfate) crystals in the solid, "melted," and dissolved form. While the "melted form" is not a true liquid phase, it can be used as an analogy for compounds with melting points too high to be obtained easily or safely in the laboratory.	
al, ionic com- end to dissolve solvents and are e in nonpolar sol-	Use small round magnets to represent the "dipole" action of water in pulling thumbtack "ions" from some prearranged order.	Electrostatic forces between the dipole solvent molecules and the ions of the crystalline solid result in the weakening of the lattice structure, and ions are pulled from their sites.

Topical Outline	Understandings and Concepts	Laborato
	The degree of solubility of a substance depends upon the solvent's ability to pull ions from the lattice structure.	
	Water is the most common solvent for ionic substances.	
V. Periodic Table		
A. Purpose	The periodic table is used to organize and classify a large body of information about the elements.	Derive a l "strip" of A 1.02 in
	The similarities and dissimilarities of properties are the basis for classifying substances.	
B. Arrangement	In the present form of the periodic table, the elements are arranged on the basis of atomic number.	Finding oth for the per makes an in assignment use of the

dings epts	Laboratory Experiences	Supplementary Information
solubility depends nt's ability rom the lat- .		
ost common nic sub-		
ble is used classify a nformation nts.	Derive a long form from a "strip" of elements. See A 1.02 in the appendix.	By learning how to use and interpret the periodic table, one can avoid memorizing a great mass of details.
s and dis- properties for classi- s.		
form of the , the ele- nged on the number.	Finding other arrangements for the periodic table makes an interesting assignment requiring the use of the library.	Early periodic tables based upon atomic "weights" led to predictions of properties of elements that were not known at the time. These predictions led to the discovery of many elements.

Topical Outline	Understandings and Concepts	Laboratory Experie
	The horizontal rows of the periodic table are called periods or rows.	
	The vertical columns of the periodic table are called groups or families.	
C. Properties	The properties of the elements depend on the structure of the atom and vary with the atomic number in a systematic way.	Appropriate activit based upon the peri table can be found tions 1, 2, and 3 c 2.22 (Melting point boiling points and ties).
	The properties of elements change systematically through a period.	Generalizations bas the periodic table listed in CH 2.21.
	The elements of a group exhibit similar or related properties.	
	Metallic properties are most pronounced in those elements on the left-hand side of the periodic table; nonmetallic, in the upper right-hand side.	

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Laboratory Experiences

Appropriate activities based upon the periodic table can be found in Sections 1, 2, and 3 of CH 2.22 (Melting points, boiling points and densities).

Generalizations based upon the periodic table are listed in CH 2.21.

Supplementary Information

Pupils will be expected to know that metals in groups on the extreme left of the table, when combined with nonmetals on the right, tend to form ionic compounds. Likewise, they will be expected to anticipate that elements relatively "near" each other on the table tend to form covalent bonds.

Topical Outline	Understandings and Concepts	Laboratory Experienc
1. Metals	Generally, the larger the atom of a metal, the less firmly it holds its valence electrons, and the more active it is.	The activity series o metals can be develop the use of CH 8.09.
2. Nonmetals	Generally, the smaller the atom of a nonmetal, the more strongly it attracts electrons and the more "electronegative" it is. Generally, the smaller the nonmetallic atom is, the more active it is. Generally, the fewer the electrons needed to complete the valence shell of a nonmetal, the more active the nonmetallic atom is.	

ings pts	Laboratory Experiences	Supplementary Information
larger the , the less its ns, and the is.	The activity series of metals can be developed by the use of CH 8.09.	While some general predictions regarding the activity of a metal can be made on the basis of its position in the periodic table, factors other than the atomic size and number of valence electrons result in many exceptions. Pupils should refer to the Electromotive Series in the *Reference Tables* to find the relative activity of metals.
smaller the tal, the t attracts he more e" it is.		
smaller the n is, the is.		
fewer the d to com- e shell of more etallic		

AREA 2 - THE PREPARATION AND SEPARATION O

Pupils should have a wide latitude of laboratory
ing a variety of techniques. Area 2 adapts itse
oratory approach so there may be more activities
done in the allotted time. Teachers should sele
iences that are most suitable to their teaching

Topical Outline	Understandings and Concepts	Laboratory E
I. Preparation of Substances	Substances may be made by chemical reactions.	
A. Energy and reactions		
1. Activation energy	A reaction requires "starting energy" called activation energy.	Activation e illustrated b of wood. Th to reach the perature is a activation e
2. Exothermic reactions	When energy is released during any reaction, the reaction is said to be exothermic.	Burning wood examples of reactions pr and light. Activities t to show exot tions are li 1.25-b. A 1 or candle wi trate an exo tion.

THE PREPARATION AND SEPARATION OF SUBSTANCES

ve a wide latitude of laboratory experiences requir-
techniques. Area 2 adapts itself well to the lab-
so there may be more activities listed than can be
tted time. Teachers should select laboratory exper-
most suitable to their teaching situations.

standings Concepts	Laboratory Experiences	Supplementary Information
may be made by eactions.		
requires "start- " called activa- y.	Activation energy may be illustrated by the burning of wood. The energy needed to reach the kindling temperature is an example of activation energy.	
y is released reaction, the s said to be .	Burning wood or carbon are examples of exothermic reactions producing heat and light. Activities that can be used to show exothermic reactions are listed in CH 1.25-b. A lighted burner or candle will also illustrate an exothermic reaction.	The energy released during an exothermic reaction may be in the form of heat, light, and/or electrical energy.

Topical Outline	Understandings and Concepts	Laboratory E
		CH 1.22-b sho energy result ical action. 0-6 volt voltı lamp.
3. Endothermic reactions	Reactions requiring the continued application of energy are called endothermic reactions.	Endothermic r be illustrate electrolysis c by CH 1.24.
4. Heat of formation	The energy released or absorbed during the formation of a compound from its elements is known as the heat of formation of the compound. When energy is released during the formation of a compound from its elements, the compound is said to have a negative heat of formation. The greater the amount of energy released, the more stable the compound. When energy is absorbed during the formation of a compound from its elements, the compound is said to	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
	CH 1.22-b shows electrical energy resulting from chemical action. Substitute a 0-6 volt voltmeter for the lamp.	
tions requiring the inued application of gy are called endo- mic reactions.	Endothermic reactions can be illustrated by the electrolysis of water and by CH 1.24.	If CH 1.24-a is used, the decomposition of mercuric oxide should be carried out in a fume hood, preferably as a teacher demonstration. Both mercury and mercury vapor are extremely toxic.
energy released or rbed during the forma- of a compound from elements is known as heat of formation of compound.		*Refer pupils to the Reference Tables for some heats of formation. Other values of heats of formation can be found in textbook tables.*
energy is released ng the formation of a ound from its elements, compound is said to a negative heat of ation. The greater amount of energy ased, the more stable compound.		
energy is absorbed ng the formation of a ound from its elements, compound is said to		

Topical Outline	Understandings and Concepts	Laboratory Exp
	have a positive heat of formation. The greater the amount of energy absorbed, the less stable the compound.	
B. Types of reactions		
1. Direct union or synthesis	Elements may combine to form a compound by a reaction called direct union or synthesis.	Burning carbon can be used to direct union re *Pupils should n directly at bur sium.*
	Two compounds may react to form a single compound.	The slaking of reaction betwee and hydrogen ch gases can be us two compounds u form another co Use the fume ho case.
2. Exchange of ions	Two ionic compounds in aqueous solution may interact by exchanging ions.	An activity inv interaction betw pounds in aqueo is listed in A
	A reaction will occur only if at least one of the products is a precipitate, a gas, or water.	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
ave a positive heat of ormation. The greater e amount of energy sorbed, the less stable e compound.		
lements may combine to orm a compound by a reac-ion called direct union r synthesis.	Burning carbon or magnesium can be used to illustrate a direct union reaction. *Pupils should not look directly at burning magnesium.*	Synthesis can also mean a series of reactions which eventually results in the formation of a desired substance.
wo compounds may react to orm a single compound.	The slaking of lime or the reaction between ammonia and hydrogen chloride gases can be used to show two compounds uniting to form another compound. **Use the fume hood in either case.**	During the slaking of lime, spattering may occur. USE CAUTION.
wo ionic compounds in queous solution may inter-ct by exchanging ions.	An activity involving the interaction between compounds in aqueous solutions is listed in A 2.01.	*Pupils should be able to use solubility tables to predict the formation of precipitates or to identify a precipitate.*
reaction will occur only f at least one of the pro-ucts is a precipitate, a as, or water.		

Topical Outline	Understandings and Concepts	Laboratory E
	If no reaction occurs when two aqueous solutions are mixed, a state of equilibrium exists.	
3. Single replacement	An element may replace a less active element in a compound. The reaction is called a single replacement.	Most laborato list exercise single replac tions.
4. Decomposition	A reaction in which a compound is broken up to form two or more simpler substances is called a decomposition.	
	Binary compounds (compounds composed of only two elements) may be decomposed to free the two elements.	Activities in decomposition compounds wer in Section I Area.
		The electroly chloride solu carried out i using carbon Do not operat long enough t ible amounts Pupils will b detect the sm of Cl_2 by the odor.

standings Concepts	Laboratory Experiences	Supplementary Information
tion occurs when s solutions are tate of equilib- s.		
may replace a e element in a The reaction is ingle replace-	Most laboratory manuals list exercises involving single replacement reactions.	The relative activities of the metals and of the halogens is given in the Electromotive Series in the *Reference Tables*.
in which a com- roken up to form e simpler sub- called a decom-		Most decomposition reactions are endothermic. The energy is generally supplied in the form of heat or electrical energy.
pounds (compounds f only two ele- be decomposed e two elements.	Activities involving the decomposition of binary compounds were indicated in Section I A 3 of this Area. The electrolysis of copper chloride solution may be carried out in a U-tube using carbon electrodes. Do not operate the cell long enough to collect visible amounts of chlorine. Pupils will be able to detect the small quantity of Cl_2 by the "Clorox" odor.	Most binary compounds are quite stable to decomposition by heat. Binary ionic compounds may be decomposed by electrolysis in the liquid phase or in aqueous solution. The very active metals may be produced by electrolysis of their fused (melted) compounds only.

Topical Outline	Understandings and Concepts	Laboratory
		Pupils shou through labo ence that du trolysis of pound, the m at the negat and the nonm positive.
	Some compounds can be decomposed into two or more compounds.	Copper (II) readily be d heat to give and CO$_2$.
		A 2.02 descri position of ca bonate.
5. Gain and loss of electrons	Many reactions involve a gain of electrons by one species and a loss of electrons by another.	As an aid to u oxidation, red redox reaction "transfer" ele using models s listed in CH 1 and CH 2.08.

Understandings and Concepts	Laboratory Experiences	Supplementary Information
	Pupils should learn through laboratory experience that during the electrolysis of a binary compound, the metal is formed at the negative electrode and the nonmetal at the positive.	
Some compounds can be decomposed into two or more compounds.	Copper (II) carbonate can readily be decomposed by heat to give copper oxides and CO_2.	A metal carbonate $\xrightarrow{\text{heat}}$ a metal oxide + CO_2. A metal chlorate $\xrightarrow{\text{heat}}$ a metal chloride + oxygen. Because of their explosive nature, the decomposition of chlorates is not recommended as a laboratory activity.
	A 2.02 describes the decomposition of calcium carbonate.	
Many reactions involve a gain of electrons by one species and a loss of electrons by another.	As an aid to understanding oxidation, reduction, and redox reactions, pupils can "transfer" electrons by using models such as are listed in CH 1.18, CH 2.07, and CH 2.08.	

Topical Outline	Understandings and Concepts	Laboratory
a. Oxidation	Oxidation is defined as the loss of electrons by an atom or ion.	
	To release nonmetals from ionic compounds, the nonmetal ion must undergo oxidation.	
	Metals are oxidized to metal ions in combining with nonmetals.	
b. Reduction	Reduction is defined as a gain of electrons by an atom or ion.	
	Nonmetals are reduced to nonmetal ions in combining with metals.	
	To release metals from their compounds, the metal ion must be reduced.	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
idation is defined as e loss of electrons by atom or ion.		Originally the term "oxidation" was applied only to reactions involving combination with oxygen. Because of the high electronegativity of oxygen, elements combining with it appear to lose electrons to the oxygen. It has been found useful to expand the definition of oxidation to include any loss of electrons.
release nonmetals from ic compounds, the nontal ion must undergo idation.		Nonmetals tend to gain electrons in forming ionic compounds with metals. To decompose the compound into its elements, the nonmetal ion must lose the electrons it has gained.
tals are oxidized to tal ions in combining th nonmetals.		
duction is defined as a in of electrons by an om or ion.		
nmetals are reduced to nmetal ions in combing with metals.		
release metals from eir compounds, the metal n must be reduced.		

Topical Outline	Understandings and Concepts	Laboratory E
c. Redox reactions	A reaction involving oxidation and reduction is called a redox reaction. Oxidation must be accompanied by reduction.	Use the electr copper chlorid to illustrate reaction. Oxi occur at the p and reduction tive pole.
III. Quantitative Relationships		
A. Mole concept	The mole is a convenient unit for use with large numbers of small particles. A mole is 6.02×10^{23} particles.	Compare the we ream of light with a ream of as a convenien comparing the individual she

Understandings and Concepts	Laboratory Experiences	Supplementary Information
A reaction involving oxidation and reduction is called a redox reaction. Oxidation must be accompanied by reduction.	Use the electrolysis of copper chloride solution to illustrate a redox reaction. Oxidation will occur at the positive pole and reduction at the negative pole.	Oxidation and reduction occur simultaneously; one cannot occur without the other. *Pupils will be required to recognize redox reactions only in cases of direct union of elements, decomposition of binary compounds, and single replacement reactions.*
The mole is a convenient unit for use with large numbers of small particles. A mole is 6.02×10^{23} particles.	Compare the weight of a ream of light weight paper with a ream of heavy bond as a convenient method of comparing the weights of individual sheets of paper.	Small particles such as atoms, molecules, ions, electrons, etc., cannot be isolated, weighed, or counted as individual units. For practical purposes it is necessary to work with large numbers of these particles. If the same number of particles is taken as a group (unit), comparison of groups will show the same ratios as comparisons of individual particles.

Topical Outline	Understandings and Concepts	Laboratory Experie
B. Chemical shorthand		
1. Symbols	A chemical symbol represents one atom of an element or one mole of atoms of the element.	
2. Formulas	A formula is composed of symbols and subscripts and indicates the composition of a substance. A formula also represents one mole of the substance.	Point out the need f carefully reading th mulas on reagent bot by using A 2.03. Suggestions for adap CH 1.17 for pupil's during formula writi be found in A 2.04.
3. Equations	An equation consists of formulas which indicate the reactants and products of a chemical reaction.	

ndings ncepts	Laboratory Experiences	Supplementary Information
		Illustrations using other number units familiar to the pupil, such as a dozen eggs or a ream of paper, may help to clarify the mole concept.
ymbol repre- om of an ele- mole of atoms nt.		
composed of subscripts and e composition ce. A formula nts one mole ance.	Point out the need for carefully reading the formulas on reagent bottles by using A 2.03.	The formula of a molecular substance represents the atoms forming the molecule and is called a molecular formula.
	Suggestions for adapting CH 1.17 for pupil's use during formula writing can be found in A 2.04.	The formula of an ionic compound represents the ratio of the elements present and is called an empirical formula. *Pupils will not be required to distinguish between molecular and empirical formulas.*
consists of ch indicate s and products l reaction.		

Topical Outline	Understandings and Concepts	Laboratory
a. Conservation of mass	Mass is conserved during a chemical reaction.	Compare the mass as exp equation, K_2CrO_4 + P $2KNO_3$ + Pb with CH 1.2
b. Balancing equations	To indicate that mass is conserved, an equation is balanced by the use of appropriate coefficients.	Adapting CH use in writ can be done similar to found in A
c. Writing equations	The formulas of the reactants are shown on the left of the arrow or equal sign and those of products on the right. Balance the equation by inserting coefficients that will result in conservation of mass.	The felt bo effective t for the pres equation wr CH 1.18.
d. Redox equations	In a redox reaction there is an oxidation and a reduction. Separate half-reaction equations may be written to show the gain and loss of electrons.	

nderstandings and Concepts	Laboratory Experiences	Supplementary Information
s conserved during a al reaction.	Compare the conservation of mass as expressed in the equation, $K_2CrO_4 + Pb(NO_3)_2 \rightarrow 2KNO_3 + PbCrO_4$, with CH 1.23.	
icate that mass is rved, an equation is ed by the use of riate coefficients.	Adapting CH 1.18 for pupil use in writing equations can be done in a manner similar to the adaptations found in A 2.04.	
rmulas of the reac- are shown on the f the arrow or equal nd those of products right. Balance the on by inserting coef- ts that will result nservation of mass.	The felt board is a very effective teaching device for the presentation of equation writing. See CH 1.18.	*Although equation writing is listed as a separate section, teachers should feel free to introduce equation writing at any point in the course.*
redox reaction there oxidation and a ion. Separate half- on equations may be n to show the gain ss of electrons.		*Pupils should be able to write simple reduction and oxidation equations to show the gain or loss of electrons. In writing simple reduction and oxidation equations, pupils should show the electrons as a reactant in reduction and as a product in oxidation.*

Topical Outline	Understandings and Concepts	Laboratory Experie
C. Mass relationships		
1. From symbols	Atomic mass is the mass of one atom of an element measured in atomic mass units.	
	Gram atomic mass is the mass of one mole of atoms of an element measured in grams.	Compare the ability balance scale to mea the mass of 1 grain sand and the mass of tablespoon or scoopf sand. Relate the si to atomic mass and g atomic mass.
	The atomic mass in amu is numerically equal to the gram atomic mass in grams.	

	Laboratory Experiences	Supplementary Information
		For example, the equation for the combination of magnesium and chlorine, $Mg + Cl_2 \rightarrow MgCl_2$, can be written as an oxidation half-reaction, $Mg^0 \rightarrow Mg^{+2} + 2e^-$ and a reduction half-reaction, $\overset{0}{Cl_2} + 2e^- \rightarrow 2Cl^-$
ass of nt ass		*The basis for relative atomic mass and the definition of an atomic mass unit were treated in Area I, Section IV A.*
the atoms red in amu is the grams.	Compare the ability of a balance scale to measure the mass of 1 grain of sand and the mass of a tablespoon or scoopful of sand. Relate the situation to atomic mass and gram atomic mass.	1 amu x (6.02×10^{23}) = 1 gram. The number in a mole (6.02×10^{23}) was chosen to provide this relationship. Chemists prefer to use the gram atomic mass since it can be measured on laboratory scales. *Pupils may round off atomic masses to the nearest whole number for the solution of*

Topical Outline	Understandings and Concepts	Laboratory Exper
2. From formulas		
a. Mole mass	The mole mass of a substance is the mass in grams of one mole of the substance.	
	The mole mass can be calculated from the formula by adding the gram atomic masses represented by the symbols making up the formula.	
	The number of moles in a given sample of a substance can be calculated by dividing the mass of the sample by the mole mass of the substance.	Find the number in given samples stances such as chunks, galena pi a "pile" of coppe crystals.
b. Percentage composition	The percentage composition of a compound can be determined experimentally or calculated from its formula.	Most laboratory include exercise the percentage c of a compound ca mined experiment

tandings oncepts	Laboratory Experiences	Supplementary Information
		problems.
ss of a sub- he mass in grams of the sub- ss can be cal- m the formula he gram atomic esented by the ing up the		*The mole mass of a molecular substance is sometimes called the gram molecular mass. The mole mass of an ionic substance is sometimes called the gram formula mass. Since the term "mole mass" applies to both, it is not necessary for pupils to distinguish between them.*
of moles in a e of a sub- be calculated the mass of by the mole substance.	Find the number of moles in given samples of substances such as calcite chunks, galena pieces, or a "pile" of copper sulfate crystals.	Sample problem: How many moles are there in 200 grams of calcite ($CaCO_3$)? Solution: Mole mass of $CaCO_3$ (from formula) = 100g. $200g.\ CaCO_3 \times \frac{1\ mole\ CaCO_3}{100g.\ CaCO_3}$ $= 2\ moles\ CaCO_3$
age composition nd can be deter- imentally or from its	Most laboratory manuals include exercises in which the percentage composition of a compound can be determined experimentally.	

Topical Outline

Understandings and Concepts

The percentage composition of a compound can be calculated from the ratio of the mass of the element represented in the formula to the mole mass of the compound, or

$$\frac{\text{mass of the element}}{\text{mole mass of the compound}} \times 100\%$$

Laboratory Expe

Some examples o

a. Calculate
water (H_2O

Solution:

Mass of hy
Mass of ox
Mole mass

% hydrogen

% oxygen

b. Find the pe
mass in gyp

Solution:

Mole mass o
Total mass

dings
epts

composition
can be cal-
he ratio of
e element
the formula
ss of the

$\frac{\text{ement}}{\text{compound}} \times 100\%$

Laboratory Experiences **Supplementary Information**

Some examples of percentage problems are:

a. Calculate the percentage composition by mass of water (H_2O).

Solution:

Mass of hydrogen, 2 x 1.0g. = 2g.
Mass of oxygen, 1 x 16g. = 16g.
Mole mass of water = 18g.

$$\%\ \text{hydrogen} = \frac{\text{mass of hydrogen}}{\text{mole mass of water}} \times 100\%$$

$$= \frac{2.0\text{g.}}{18\text{g.}} \times 100\%$$

$$= 11\%$$

$$\%\ \text{oxygen} = \frac{\text{mass of oxygen}}{\text{mole mass of water}} \times 100\%$$

$$= \frac{16\text{g.}}{18\text{g.}} \times 100\%$$

$$= 89\%$$

b. Find the percentage of water of hydration by mass in gypsum ($CaSO_4 \cdot 2H_2O$).

Solution:

Mole mass of gypsum = 172g.
Total mass of water in formula = 36g.

Topical Outline	Understandings and Concepts	Laboratory Experien
		$\% \text{ water} = \frac{\text{tota}}{\text{mole}}$ $= \frac{36g}{172g}$ $= 21\%$
3. From equations	The reactants and products of a reaction are in a definite mole ratio. The relative numbers of moles of reactants and products are indicated by the coefficients of the formulas represented in a balanced equation. It is possible to predict the mass of a product that will be formed from a specific mass of reactant. The mass of a reactant needed to combine with a specific mass of another reactant to make a specified mass of a product can also be calculated.	The combining mole r is shown by A 2.05. Sample problem: How many grams of produce 350 grams solution is: $2NaCl \rightarrow 2Na + C$ Step 1: Change p $350g.\ Cl_2 \times \frac{1}{7}$ Step 2: From mol from mol $5 \text{ moles } Cl_2 \times$ Step 3: Change m 10 moles NaCl

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another
a speci-
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Laboratory Experiences

Supplementary Information

$$\%\ \text{water} = \frac{\text{total mass of water}}{\text{mole mass of gypsum}} \times 100\%$$

$$= \frac{36\text{g.}}{172\text{g.}} \times 100\%$$

$$= 21\%$$

The combining mole ratio is shown by A 2.05.

Sample problem:

How many grams of sodium chloride are needed to produce 350 grams of chlorine gas? One method of solution is:

$2NaCl \rightarrow 2Na + Cl_2$

Step 1: Change problem data to moles:

$$350\text{g. } Cl_2 \times \frac{1 \text{ mole } Cl_2}{70\text{g. } Cl_2} = 5 \text{ moles } Cl_2$$

Step 2: From moles of Cl_2 calculate moles of NaCl from mole ratio in equation:

$$5 \text{ moles } Cl_2 \times \frac{2 \text{ moles NaCl}}{1 \text{ mole } Cl_2} = 10 \text{ moles NaCl}$$

Step 3: Change moles NaCl to grams

$$10 \text{ moles NaCl} \times \frac{58\text{g. NaCl}}{1 \text{ mole NaCl}} = 580\text{g. NaCl}$$

Topical Outline	Understandings and Concepts	Laboratory
		Students matical r in one ec Mass of N 350g. = 580
D. Volume relationships	Equal volumes of gases under the same conditions of temperature and pressure contain an equal number of particles.	Mole-volume apply only t phase.
1. Mole volume	A mole of any gas contains 6.02×10^{23} particles. Therefore a mole of any gas will have the same volume as a mole of any other gas at the same temperature and pressure. The volume of a mole of gas at S.T.P. is 22.4 liters.	
2. Combining volumes	In a reaction involving gases, the coefficients in the balanced equation indicate the volume ratios of the gases in the reaction.	Sample pr In the r volume o NH_3.

erstandings d Concepts	Laboratory Experiences	Supplementary Information
		Students who are sufficiently proficient in mathematical manipulations can combine the three steps in one equation: Mass of NaCl needed = $350g.\ Cl_2 \times \frac{1\ mole\ Cl_2}{70g.\ Cl_2} \times \frac{2\ moles\ NaCl}{1\ mole\ Cl_2} \times \frac{58g.\ NaCl}{1\ mole\ NaCl}$ $= 580g.\ NaCl$
olumes of gases he same conditions erature and pres- ntain an equal num- particles.	Mole-volume relationships apply only to the gaseous phase.	
of any gas contains 10^{23} particles. re a mole of any l have the same as a mole of any as at the same tem- e and pressure. ume of a mole of S.T.P. is 22.4		
eaction involving the coefficients in lanced equation te the volume ratios gases in the reac-		Sample problem: In the reaction $N_2 + 3H_2 \rightarrow 2NH_3$, calculate the volume of hydrogen required to form 100 liters of NH_3.

Topical Outline | Understandings and Concepts | Laboratory Experience

Solution:

Equation:

$N_2 + 3H_2 \rightarrow 2NH$

Mole ratio:

1 3 2

When reacting gases
pressure, the volum
ratio.

Since the mole rati
volumes of the gase
Therefore:

volume of H_2 needed = (mol / mol

= (3 m / 2 m

= 150

An alternate soluti

From the equation,

$\frac{\text{x liters}}{\text{3 moles}} = \frac{\text{100 li}}{\text{2 mo}}$

(150 liters of H_2

Solution:

Equation:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

Mole ratio:

1 3 2

When reacting gases are at the same temperature and pressure, the volume ratio is equal to the mole ratio.

Since the mole ratio between H_2 and NH_3 is 3:2, the volumes of the gases are in the same ratio. Therefore:

$$\begin{aligned} \text{volume of } H_2 \text{ needed} &= \left(\frac{\text{moles } H_2}{\text{moles } NH_3}\right)\left(\text{volume of } NH_3 \text{ produced}\right) \\ &= \left(\frac{3 \text{ moles } H_2}{2 \text{ moles } NH_3}\right)(100 \text{ liters } NH_3) \\ &= 150 \text{ liters } H_2 \end{aligned}$$

An alternate solution:

From the equation, the proportion:

$\frac{x \text{ liters}}{3 \text{ moles}} = \frac{100 \text{ liters}}{2 \text{ moles}}$ will yield the same answer

(150 liters of H_2)

Topical Outline	Understandings and Concepts	Laboratory Experien
III. Preparation of Solutions	Many chemical reactions are carried out in aqueous solutions.	
A. Rate of dissolving	The rate of dissolving is the quantity of solute dissolving per unit of time.	Ask pupils to find t quickest way to diss large pieces of soli such as sugar cubes large crystals of so soluble salt.
	The process of dissolving occurs only at the surface of the solid.	
	The rate of dissolving is affected by such factors as surface area, agitation, and temperature.	
B. Solubility	The solubility of a substance is defined as the quantity of the substance that can be dissolved in a stated amount of solvent at a specified temperature.	
1. Nature of solute and solvent	Polar solvents tend to dissolve only polar and ionic solutes; nonpolar solvents tend to dissolve only nonpolar solutes.	

Laboratory Experiences	Supplementary Information
	Material on solutions is treated in Block J, pp. 60-65, and in Area I, Section III C of this syllabus.
Ask pupils to find the quickest way to dissolve large pieces of solids such as sugar cubes or large crystals of some soluble salt.	
	Review the dipole action of water on a crystal lattice in Area 1, Section IV B 2.
	Pupils should be able to read and use the solubility charts on the Reference Tables.

Topical Outline	Understandings and Concepts	Laboratory Experi
2. Temperature	Most solids become more soluble as the temperature increases. Gases become less soluble as the temperature increases.	
3. Pressure	The solubility of gases varies directly with the pressure on the gas.	
C. Concentration	The concentration of a solution may be expressed in a variety of ways.	
1. Concentrated and dilute solutions	A concentrated solution contains a relatively large amount of solute. A dilute solution contains a relatively small amount of solute.	Make a series of d of copper sulfate and compare the de color of the solut Evaporate some of vent from a copper solution and notic depth of color.
2. Saturated, unsaturated, and supersaturated solutions	A saturated solution is a solution containing all the solute that can be dissolved at the temperature of the solution. An unsaturated solution is one in which more solute can be dissolved without changing the temperature	Sodium thiosulfate is a suitable solu making solutions c degrees of saturat

rstandings Concepts	Laboratory Experiences	Supplementary Information
ds become more s the temperature .		
ome less soluble mperature .		
ility of gases rectly with the on the gas.		
ntration of a solu- be expressed in of ways.		
rated solution a relatively unt of solute.	Make a series of dilutions of copper sulfate solution, and compare the depth of color of the solutions.	Because the definitions of concentrated and dilute solutions are vague, they are useful only in comparing different solutions of the same solute. The terms listed below have a more common usage.
solution contains ely small amount .	Evaporate some of the solvent from a copper sulfate solution and notice the depth of color.	
ed solution is a containing all e that can be dis- the temperature lution.	Sodium thiosulfate (hypo) is a suitable solute for making solutions of varying degrees of saturation.	
rated solution is ich more solute ssolved without the temperature		

Topical Outline	Understandings and Concepts	Laborat
	of the solution.	
	A supersaturated solution is one which contains more dissolved solute than it normally would have at that temperature.	
3. Mass/volume	The concentration of a solution may be expressed in a mass/volume ratio.	
	Common units used to express concentration are g./liter, g./ml., and mg./ml.	
	The mass of a solute in a given solution can be found: volume x mass/volume = mass of solute. The two volume units must be the same.	
4. Molarity	The molarity of a solution indicates the number of moles of solute per liter of solution.	Pupils sh ence in p of differ Use CH 3. tory exer found in manuals.

tandings oncepts	Laboratory Experiences	Supplementary Information
tion.		
rated solution h contains more olute than it uld have at that .		A supersaturated solution is prepared by cooling a saturated solution.
ration of a y be expressed olume ratio.		Many recent laboratory manuals express concentration in a mass/volume ratio.
s used to centration are ./ml., and		Nursing students will encounter percentage solutions. Percentage solutions = parts solute/100 parts solution.
a solute in a ion can be ume x mass/vol- of solute. The units must be		Small quantities of solute are sometimes expressed as parts of solute per million parts of solvent, or parts per million (ppm).
y of a solution he number of lute per liter .	Pupils should have experience in preparing solutions of different molarities. Use CH 3.26 or the laboratory exercises on molarity found in most laboratory manuals.	The prepared standard solutions may be saved for uses in other experiments.

Topical Outline	Understandings and Concepts	Laborator
	The mass of solute in a given volume of molar solutions can be computed: mass of solute = $\text{molarity x } \frac{\text{mole mass}}{\text{mole}}$ x volume (in liters). A standard solution is one in which the molarity is known.	
IV. Separation of Substances	Mixtures of substances can be separated on the basis of differences in properties of the components. Two common methods are based on differences in solubility and boiling points.	

erstandings d Concepts	Laboratory Experiences	Supplementary Information
of solute in a lume of molar s can be computed: solute = x $\frac{\text{mole mass}}{\text{mole}}$ (in liters).		The quantities used must be expressed in proper units. For example: grams = $\frac{\text{moles}}{\text{liter}}$ x $\frac{\text{gram(s)}}{\text{mole}}$ x liter(s).
rd solution is one the molarity is		
of substances can ated on the basis rences in proper- the components. on methods are differences in ty and boiling		The allowable amounts of impurities present in a reagent are set by various agencies. Work in the laboratory requires a degree of purity found in CP, USP, or reagent grades. Technical grade contains the highest amounts of impurities and is used only in industrial processes where the impurities do not affect the process.

Topical Outline	Understandings and Concepts	Laboratory Exper
A. Separation by solubility	Soluble substances can be separated from insoluble ones by dissolving the soluble ones.	
1. Filtration	Undissolved materials may be isolated by filtration.	Ask pupils to iso many substances a can from an unknow mixture. Such a might include san stone or chalk, a sodium chloride.
2. Crystallization	Since most solutes are more soluble in hot water than cold, cooling a solution (or filtrate) generally causes some of the solute to crystallize out.	Pupils should be a use decanting and filtering techniq These techniques a in connection wit separation of crys
	Crystals suspended in a solution can be isolated by filtration.	Pupils should be a recover solutes b ration of filtrate (Spattering during ration can be decr using a heat lamp above the evaporat as the heat source
B. Separation by boiling points	Distillation is a process by which a liquid is vaporized and recondensed.	Use a distillation to find the percen water in vinegar. pupils plan their experiment, some w up with a percent

Laboratory Experiences	Supplementary Information
Ask pupils to isolate as many substances as they can from an unknown solid mixture. Such a mixture might include sand, limestone or chalk, and sodium chloride.	
Pupils should be able to use decanting and vacuum filtering techniques. These techniques are used in connection with the separation of crystals.	No sample can be 100% pure. There are always traces of other substances. The process by which the amount of contamination components is significantly reduced is called purification.
Pupils should be able to recover solutes by evaporation of filtrates. (Spattering during evaporation can be decreased by using a heat lamp mounted above the evaporating dish as the heat source.)	When contaminating materials have been reduced to such an extent that their effect is no longer significant, the substance is considered to be "pure."
Use a distillation process to find the percent of water in vinegar. If pupils plan their own experiment, some will end up with a percent by volume	

Topical Outline	Understandings and Concepts	Laboratory Exper
	The recondensed liquid which is collected is called the distillate.	and others, with by mass. Since v about 95 percent some teachers may concentrate it be for quicker and m accurate results.
	A liquid may be isolated from high boiling point (nonvolatile) impurities by distillation.	
	Volatile components can often be separated by the use of fractional distillation.	Ask pupils to fin amount of alcohol fraction collecte the fractional di of an ethanol-wat ture. Specific g ethanol solutions found in chemical books.
	Successive samples or fractions contain decreasing amounts of low boiling point components and increasing amounts of higher boiling point components.	
	Repeated fractional distillation of a specific fraction can be used for further separation.	

nderstandings and Concepts	Laboratory Experiences	Supplementary Information
condensed liquid is collected is the distillate.	and others, with a percent by mass. Since vinegar is about 95 percent water, some teachers may prefer to concentrate it beforehand for quicker and more accurate results.	
id may be isolated igh boiling point latile) impurities illation.		
le components can be separated by the fractional distil-	Ask pupils to find the amount of alcohol in each fraction collected during the fractional distillation of an ethanol-water mixture. Specific gravity of ethanol solutions can be found in chemical handbooks.	There is a U.S. tax on ethanol used in intoxicating beverages. To avoid the high tax, industry uses a denatured ethanol solvent which contains "impurities" which are very difficult to remove and which make the alcohol poisonous.
ive samples or frac- ontain decreasing of low boiling components and ing amounts of boiling point com- .		
d fractional dis- on of a specific n can be used for separation.		

AREA 3 - STRUCTURE AND PROPERTIES OF SIMPLE ORGANIC

In some areas, working with models provides grea
understanding than working with the actual subst
ces. In this unit suggested laboratory experien
will emphasize the use of models. It is recomme
that each pupil have a set of models.

Topical Outline	Understandings and Concepts	Laboratory Experienc
I. Organic Compounds		
A. Definition	Organic compounds are compounds of carbon.	
B. General properties	Organic compounds tend to be soft, low-boiling point solids, or gases.	Arrange a display of organic materials amo which might be paraff wax, an alcohol, prop turpentine, and an es such as amyl acetate.
	Organic compounds are more easily decomposed by heat than inorganic compounds.	
	Organic compounds usually are nonconductors of electricity.	Show that glycerol, s and alcohol solutions not conductors of ele tricity.

ND PROPERTIES OF SIMPLE ORGANIC COMPOUNDS

orking with models provides greater
an working with the actual substan-
it suggested laboratory experiences
he use of models. It is recommended
have a set of models.

s	Laboratory Experiences	Supplementary Information
are com-		*Pupils will have encountered some of the concepts listed at the left in Science 7, 8, 9, Block L (pp. 62-75).* Other definitions of organic compounds will not be treated in this course.
tend to ng point	Arrange a display of organic materials among which might be paraffin wax, an alcohol, propane, turpentine, and an ester such as amyl acetate.	An odor indicates a low boiling point.
are more by heat npounds.		Organic compounds tend to char when heated.
usually of elec-	Show that glycerol, sugar, and alcohol solutions are not conductors of electricity.	

Topical Outline	Understandings and Concepts	Laboratory Exper
	The solubility of organic compounds depends upon the nature of the solvent used.	
	Since many organic compounds are nonpolar, they are not soluble in water. They are soluble in nonpolar solvents such as petroleum ether, carbon tetrachloride, and cyclohexane.	
	Organic compounds tend to react more slowly than inorganic compounds.	
	There are many more organic compounds than inorganic compounds.	

dings epts	Laboratory Experiences	Supplementary Information
of organic nds upon the olvent used.		Oil or kerosene will not dissolve in water, but will dissolve in nonpolar organic solvents. Oil contains nonpolar molecules, while water has polar molecules. Generally, "like tends to dissolve like."
nic com- olar, they in water. e in non- such as , carbon and cyclo-		The toxic nature and flammability of most organic solvents make them unsuitable for use in high schools.
ds tend to ly than unds.		A notable exception is the speed with which some organic reactions occur in living things.
more organic inorganic		Known inorganic compounds number about 50,000 compared to some 1,000,000 or more organic compounds. More impressive than the relative numbers is the fact that virtually all new chemical compounds being discovered can be classified as organic compounds. The number of new

Topical Outline	Understandings and Concepts	Laboratory Experiences
II. Bonding in Organic Compounds	Generally, molecules of organic compounds are covalently bonded. The carbon atom has four valence electrons, each of which can be used in forming a covalent bond. The carbon atom tends to form four covalent bonds to achieve a complete eight-electron valence ring.	A satisfactory device to illustrate the arrangement of covalent bonds in a variety of organic compounds is a set of molecular models. The models consist of wooden spheres with one to five holes in them and dowels or springs to represent the covalent bonds. Prices range from $3. to over $75. A set costing less than $10. is usually satisfactory for use at this level. These sets may also be constructed of styrofoam spheres and dowels.
	The carbon atom is considered to have a tetrahedral structure.	Directions for constructing a regular tetrahedron are given in A 3.01. Use the ball-and-stick model to show the bond angles. Insert four sticks into the ball representing the carbon atom. Show that the "ends" of any three sticks represent the vertices of an equilateral triangle.

	Laboratory Experiences	Supplementary Information
		compounds averages at least 30,000 per year.
s of re four each of n form- . ds to bonds te nce	A satisfactory device to illustrate the arrangement of covalent bonds in a variety of organic compounds is a set of molecular models. The models consist of wooden spheres with one to five holes in them and dowels or springs to represent the covalent bonds. Prices range from \$3. to over \$75. A set costing less than \$10. is usually satisfactory for use at this level. These sets may also be constructed of styrofoam spheres and dowels.	
consid- ahedral	Directions for constructing a regular tetrahedron are given in A 3.01.	The angle between adjacent bonds tends to be 109°28'.
	Use the ball-and-stick model to show the bond angles. Insert four sticks into the ball representing the carbon atom. Show that the "ends" of any three sticks represent the vertices of an equilateral triangle.	

Topical Outline	Understandings and Concepts	Laboratory Experi
	Carbon atoms have the ability to produce long chains or rings by forming covalent bonds with other carbon atoms.	"Build" carbon cha hooking 20 to 40 p clips together. E represents a carbo
A. Isomers	The same atoms may often be bonded in more than one spatial arrangement to form compounds having different structures and properties. Compounds having the same molecular formulas (thus the same number of each kind of atom) but different structures and properties are called isomers. As the number of atoms in a molecule increases, the possibility of more spatial arrangements (isomers) increases.	To develop the con isomers, ask pupil "bond" 6 carbon an hydrogen "atoms" f molecular model ki identical arrangem are made by the pu ask them to find o sible ways of putt atoms together.
B. Structural formulas	Structural formulas can be written by the use of a short line or dash between symbols to represent each covalent bond.	Have pupils write tural formulas for model arrangements bon and hydrogen " constructed in the ity above. Display a number o of molecules and a to write a structu mula for each "mo

tandings Concepts	Laboratory Experiences	Supplementary Information
s have the abil- uce long chains forming cova- with other car-	"Build" carbon chains by hooking 20 to 40 paper clips together. Each clip represents a carbon atom.	The ability of carbon atoms to form chains and rings accounts for the large number of possible compounds.
oms may often n more than one angement to form aving different and properties. aving the same ormulas (thus mber of each m) but different and properties isomers. er of atoms in increases, the of more spatial s (isomers)	To develop the concept of isomers, ask pupils to "bond" 6 carbon and 14 hydrogen "atoms" from their molecular model kits. If identical arrangements are made by the pupils, ask them to find other possible ways of putting the atoms together.	*Pupils should be able to recognize isomers by comparing molecular formulas. For example,* C_2H_5OH *and* CH_3OCH_3 *have the same molecular formula,* C_2H_6O*, and hence are isomers.*
formulas can be the use of a or dash between represent each nd.	Have pupils write structural formulas for the model arrangements of carbon and hydrogen "atoms" constructed in the activity above. Display a number of "models" of molecules and ask pupils to write a structural formula for each "molecule."	A structural formula is a two-dimensional representation of a three-dimensional molecule.

Topical Outline	Understandings and Concepts	Laboratory Experiences
C. Saturated and unsaturated compounds	Each carbon atom in a compound may be joined to another carbon atom by sharing one pair of electrons (one covalent bond). This compound is considered saturated.	
	Two carbon atoms in a compound may be joined by sharing two or three pairs of electrons. This compound is considered unsaturated.	

standings
Concepts

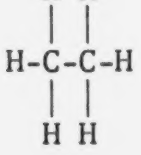
n atom in a com be joined to rbon atom by e pair of elec- covalent bond). und is consid- ated.

atoms in a com- be joined by o or three pairs ns. This com- onsidered unsat-

Laboratory Experiences

Supplementary Information

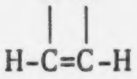
A bond formed between atoms by the sharing of one pair of electrons is called a single bond. An example of a saturated compound is ethane (C_2H_6) represented as:



$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

A bond formed between atoms by the sharing of two pairs of electrons is called a double bond; a bond formed by the sharing of three pairs of electrons is called a triple bond.

Examples of unsaturated compounds are C_2H_4 and C_2H_2. Their structural formulas are:



$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & = & C & - & H \end{array}$$

and $H-C\equiv C-H$

Topical Outline	Understandings and Concepts	Laboratory Experiences
D. Homologous series	Organic compounds can be classified into groups having related structures and properties. Such groups are called homologous series.	
	Each consecutive member of an homologous series differs from the one before it by a common increment.	The use of models will h illustrate that the incr ment is CH_2 for the seri covered in this unit.
III. Some Classes of Organic Compounds	Classes of organic compounds may be recognized by the numbers and arrangements of certain atoms or groups of atoms in their structural formulas.	
A. Hydrocarbons	Hydrocarbons are compounds containing only atoms of hydrogen and carbon.	Ask pupils to build mode of hydrocarbons represen by structural formulas. This activity will help develop an understanding the spatial relationship involved.
	Hydrocarbons may be in the form of straight chains or rings, and may contain from 1 to over 40 carbon atoms.	
	Hydrocarbons may be gases, liquids with a low boiling point, or solids with a low melting point.	Handbooks can be used fo a comparison of melting points and boiling point of hydrocarbons.

andings ncepts	Laboratory Experiences	Supplementary Information
ounds can be nto groups ed structures es. Such alled homolo-		
tive member of s series dif- e one before on increment.	The use of models will help illustrate that the increment is CH_2 for the series covered in this unit.	
rganic com- e recognized rs and arrange- tain atoms or oms in their ormulas.		The major sources of raw materials from which organic chemicals are obtained are petroleum, coal, wood and other plant products, and animals.
are compounds nly atoms of carbon.	Ask pupils to build models of hydrocarbons represented by structural formulas. This activity will help develop an understanding of the spatial relationships involved.	The most abundant sources of hydrocarbons are petroleum and natural gas.
may be in the ight chains or ay contain er 40 carbon		
may be gases, a low boiling lids with a point.	Handbooks can be used for a comparison of melting points and boiling points of hydrocarbons.	

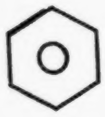
Topical Outline	Understandings and Concepts	Laboratory E
	The nonpolar nature of the hydrocarbon molecules make them relativley insoluble in water.	
	When burned, hydrocarbons form water and products such as carbon, carbon monoxide, and carbon dioxide.	Most chemistr manuals descri ties involvin tion of methan gas) in Bunse
1. Alkane series	The alkane series consists of hydrocarbons having the general formula, C_nH_{2n+2}.	Build ball-and for the first of the alkane
	The alkanes are saturated hydrocarbons since only single bonds exist between adjacent carbon atoms.	
	Isomerism is shown beginning with the fourth member, butane, of the alkane series.	Build models o of butane and
	There is a systematic way of naming organic compounds based upon the number of carbon atoms in the alkane chain.	

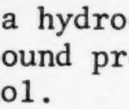
rstandings Concepts	Laboratory Experiences	Supplementary Information
ar nature of the n molecules make ivley insoluble		
d, hydrocarbons and products rbon, carbon mon- carbon dioxide.	Most chemistry laboratory manuals describe activities involving the combustion of methane (natural gas) in Bunsen burners.	The products of combustion are determined by the amount of oxygen present and by the temperature. Complete combustion results in the formation of CO_2 and H_2O. Incomplete combustion may result in the formation of H_2O, CO, and/or C.
series consists rbons having the rmula, C_nH_{2n+2}. s are saturated ns since only ds exist between arbon atoms.	Build ball-and-stick models for the first five members of the alkane series.	The alkane series is also called the methane series, or the paraffin series.
is shown begin- the fourth mem- e, of the alkane	Build models of the isomers of butane and pentane.	
systematic way organic compounds the number of ms in the alkane		*For purposes of examination, pupils will be held responsible for the names and formulas of the first ten normal (unbranched)*

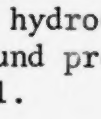
Topical Outline	Understandings and Concepts	Laboratory Experien
	The number of carbon atoms is indicated by the first part of a name. For example, meth - 1 carbon atom eth - 2 carbon atoms prop - 3 carbon atoms but - 4 carbon atoms	
	The letters "-ane" are used for the ending of an alkane's name.	
2. Unsaturated hydrocarbons	There are several homologous series of unsaturated hydrocarbons. Unsaturated hydrocarbons are named from the corresponding alkane, with the ending "-ane" changed to indicate the series to which the compound belongs. The alkene series contains one double bond in the hydrocarbon chain. The alkyne series contains one triple bond in the hydrocarbon chain.	Ball-and-stick model be built to illustra structure of alkenes alkynes. Spring con will be necessary fo double and triple bo nections. Pupils wi cover how the number hydrocarbons in thes series compares with corresponding alkane
3. Cyclic hydrocarbons	Some series of hydrocarbons contain carbon atoms arranged to form a ring structure.	In building models of zene, spring connecto will be necessary for double bond connectio

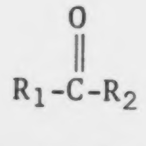
standings Concepts	Laboratory Experiences	Supplementary Information
of carbon atoms ed by the first name. For carbon atom carbon atoms carbon atoms carbon atoms s "-ane" are used ding of an ame.		*members of the alkane series, and for recognizing isomers of butane and pentane from their structural formulas. In this area pupils will not be responsible for the I.U.C naming of these isomers. The naming of hydrocarbon isomers will be treated in optional Area 4.*
several homolo- s of unsaturated ns. d hydrocarbons from the corres- kane, with the ne" changed to he series to compound belongs. series contains bond in the n chain. The ies contains one d in the hydro- n.	Ball-and-stick models can be built to illustrate the structure of alkenes and alkynes. Spring connectors will be necessary for double and triple bond connections. Pupils will discover how the number of hydrocarbons in these series compares with the corresponding alkanes.	*Pupils will not be held responsible for the names or formulas of individual alkenes or alkynes in Area 3. Unsaturated hydrocarbons will be treated in greater detail in optional Area 4.*
of hydrocarbons bon atoms form a ring	In building models of benzene, spring connectors will be necessary for double bond connections.	While alternate double and single bonds are shown in the structural formula of benzene to satisfy the valence requirements of

Topical Outline	Understandings and Concepts	Laboratory Experienc
	The most important series of cyclic hydrocarbons is the benzene series.	
	Benzene, the first member of the series, has the molecular formula C_6H_6, with the six carbon atoms forming a ring structure.	
B. Other organic compounds	In some homologous series of organic compounds one or more hydrogen atoms of a hydrocarbon have been replaced by other elements.	
	Organic compounds often can be considered as being composed of one or more functional groups attached to a hydrocarbon molecule.	
	A functional group is a particular arrangement of a few atoms which gives characteristic properties to an organic molecule.	The use of ball-and- models can provide a opportunity for deve understanding of the of the functional gr

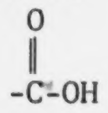
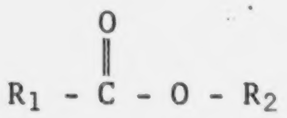
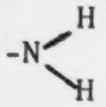
standings Concepts	Laboratory Experiences	Supplementary Information
mportant series hydrocarbons is e series. he first member ies, has the formula C_6H_6, ix carbon atoms ring structure.		the carbon atoms, all carbon-carbon bonds are the same, and the benzene ring does not show the reactions typical of unsaturated compounds. *For purposes of examination benzene will be represented as:* 
omologous series compounds one ydrogen atoms of rbon have been y other elements. ompounds often can ered as being com- one or more func- oups attached to rbon molecule.		The purpose of this section is to introduce pupils to a few classes of organic compounds and to show them how to recognize the classes from their functional groups. Naming of the compounds will not be stressed.
nal group is a r arrangement of ms which gives istic properties anic molecule.	The use of ball-and-stick models can provide an opportunity for developing understanding of the role of the functional groups.	*More detailed treatment of organic compounds and an introduction to some of their reactions may be found in optional Area 4.*

Topical Outline	Understandings and Concepts	Laboratory Exper
	Organic compounds are usually named from their corresponding hydrocarbons but are not necessarily prepared from the hydrocarbon.	
1. Alcohols	The functional group, -OH, substituted for a hydrogen atom in a hydrocarbon gives the compound properties of an alcohol.	Change alkane mod models of alcohol that an homologou of alcohols will from replacing an gen atom of succe bers of the alkan
	While an alcohol may have more than one -OH group, no more than 1 -OH group can be attached to one carbon atom in the molecule.	
	In the case of alcohols, the -OH functional group does not form hydroxide ions in aqueous solution.	Compare the effec aqueous alcohol a solutions on indi Account for the d results.
	Alcohols may be named from the corresponding hydrocarbon by replacing the final "e" by "ol."	
2. Aldehydes	The structural representation of the aldehyde group is  $-\overset{\overset{O}{\Vert}}{C}-H$	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
ic compounds are ly named from their sponding hydrocarbons re not necessarily red from the hydrocar-		
unctional group, -OH, ituted for a hydrogen in a hydrocarbon gives ompound properties of cohol.	Change alkane models into models of alcohols. Show that an homologous series of alcohols will result from replacing an end hydrogen atom of successive members of the alkane series.	The general structural formula of an alcohol is R-OH, where R represents any hydrocarbon minus one H.
an alcohol may have than one -OH group, re than 1 -OH group e attached to one car- tom in the molecule.		
e case of alcohols, OH functional group not form hydroxide in aqueous solution.	Compare the effect of aqueous alcohol and base solutions on indicators. Account for the different results.	
ols may be named from orresponding hydro- n by replacing the "e" by "ol."		Two common alcohols are methanol, CH_3OH, and ethanol, C_2H_5OH.
tructural representa- of the aldehyde group  $-\overset{\overset{O}{\Vert}}{C}-H$		An aldehyde of primary importance is methanal, HCHO, which is generally referred to by its common name, formaldehyde. Pupils should be familiar with formaldehyde, which is

Topical Outline	Understandings and Concepts	Laboratory Experience
	Aldehydes can be named by replacing the final "e" of the corresponding hydrocarbon with the ending "al."	
3. Ketones	The structural representation of the ketone group is  $R_1-\overset{\overset{O}{\parallel}}{C}-R_2$ Ketones can be named by replacing the final "e" of the corresponding alkane with "-one."	
4. Ethers	The structural representation of an ether group is R_1-O-R_2. An ether group has an oxygen atom as part of its chain.	Compare models of C_2H_5O an alcohol; CH_3CHO, an aldehyde; and CH_3OCH_3, ether. The last is the only one where O is bon to two carbon atoms.
5. Organic acids	Organic acids are characterized by a functional group called the carboxylic group.	Using a model, derive a organic acid from an al

	Laboratory Experiences	Supplementary Information
ed by 'e" of drocar- 'al."		often used to preserve biological specimens.
enta- oup		
		R_1 and R_2 must be from a hydrocarbon.
by e" of ane		An important ketone, widely used as a solvent, is propanone, CH_3COCH_3, generally referred to by its common name, acetone.
enta- p is oxy- ts	Compare models of C_2H_5OH, an alcohol; CH_3CHO, an aldehyde; and CH_3OCH_3, an ether. The last is the only one where O is bonded to two carbon atoms.	The ether used as an anaesthetic has the formula $C_2H_5OC_2H_5$.
rac- al oxylic	Using a model, derive an organic acid from an alkane.	There are acids which have other functional groups in addition to a carboxylic group. Amino acids are an example.

Topical Outline	Understandings and Concepts	Laboratory Experien
	The carboxylic group has the structure  $-\overset{O}{\overset{\|}{C}}-OH$	
	Organic acids are named from their corresponding hydrocarbons by replacing the final "-e" with the ending "-oic" and adding the class name, acid.	
6. Esters	The structure of the ester is  $R_1 - \overset{O}{\overset{\|}{C}} - O - R_2$	
7. Amine group	Amine group structure is represented by 	See A 4.08-a.
8. Amino acids	An amino acid is an organic compound containing both an amine group ($-NH_2$) and an organic acid group ($-COOH$).	See A 4.08-b.

ındings ıcepts	Laboratory Experiences	Supplementary Information
ic group has e DH		Organic acids containing long hydrocarbon chains (often 14-18 carbon atoms) are found as constituents of fats, and are known as fatty acids.
s are named orresponding by replacing e" with the " and adding ne, acid.		Methanoic acid, HCOOH, and ethanoic acid, CH_3COOH, will be familiarly known by their common names, formic acid and acetic acid.
of the ester - O - R_2		Esters generally have odors of fruit or mint. Esters are often used in synthetic flavoring. *The production of esters by condensation reactions between an alcohol and an acid will be treated in optional Area 4.*
tructure is y	See A 4.08-a.	
is an und containing group (-NH_2) c acid group	See A 4.08-b.	Units of amino acids can function as an amine, as an acid, or as both.

AREA 4 - FURTHER STUDY OF ORGANIC COMPO

Area 4 is an expansion and continuatio
of subject matter introduced in Area 3
Teachers electing this optional area m
wish to incorporate the material of bo
areas in a single organic chemistry un

Topical Outline	Understandings and Concepts	Laboratory E
I. Hydrocarbons		
A. Series of hydrocarbons	There are many homologous series of hydrocarbons. The members of a series have related structures and properties.	
1. Alkanes	The alkanes are saturated hydrocarbons having the general formula C_nH_{2n+2}. The alkanes range from gases to low-melting point solids.	

4 - FURTHER STUDY OF ORGANIC COMPOUNDS

4 is an expansion and continuation ubject matter introduced in Area 3. hers electing this optional area may to incorporate the material of both s in a single organic chemistry unit.

derstandings nd Concepts	Laboratory Experiences	Supplementary Information
		The IUPAC (International Union of Pure and Applied Chemistry) system of naming will be used in this area. There will be a few exceptions where common usage may be desired. For example, nursing students will need to know that ethanol is also called ethyl alcohol.
re many homologous of hydrocarbons. bers of a series lated structures perties.		There are series of hydrocarbons not included in this area.
anes are saturated rbons having the formula C_nH_{2n+2}.		The ending "-ane" indicates the saturated series.
anes range from o low-melting point		The first four members of the alkane series are gases at room temperature; those from C_5H_{12} to $C_{16}H_{34}$ liquids, and those above

Topical Outline	Understandings and Concepts	Laboratory Ex
	The alkanes show isomerism beginning with butane.	
	In naming the normal or straight chain isomers, the first part of the name indicates the number of carbon atoms in the molecule.	
	In naming branched-chain isomers, the longest unbranched chain of carbon atoms in the molecule is used as the basis of the name.	

rstandings
 Concepts

es show isomerism
 with butane.

 the normal or
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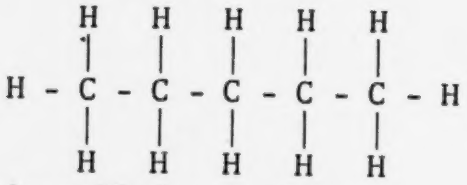
Laboratory Experiences

Supplementary Information

$C_{16}H_{34}$ are solids.

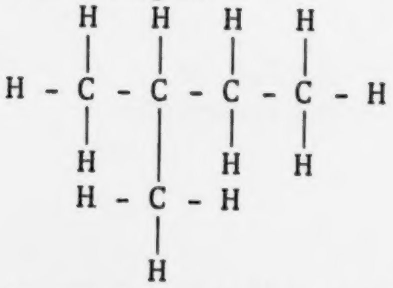
Beginning with five carbon atoms the first part of the name is a Greek (or Latin) prefix indicating the number of carbon atoms.



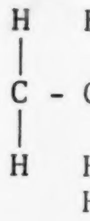
$$H-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-\overset{\overset{H}{|}}{\underset{\underset{H}{|}}{C}}-H$$

is called n-pentane.

For example:



is named as a derivative of butane.

Topical Outline	Understandings and Concepts	Laboratory Exper
	The branch chains are named as derivatives of alkanes, with the ending "-yl" substituted for "-ane."	 2 met
	The carbon atom to which the branch is attached is indicated by a number preceding the name. The chain is numbered from the end nearest the first attached group.	
2. Alkenes	The alkenes are unsaturated hydrocarbons having 1 pair of carbon atoms with a double bond between them.	Build models of th five members of th series.
	The alkene series is represented by the general formula, C_nH_{2n}.	
	In naming alkenes, the "-ane" of the corresponding alkane is dropped and the "-ene" ending is substituted to show the	

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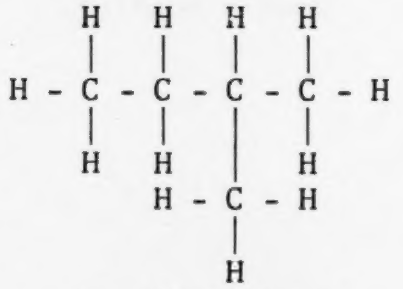
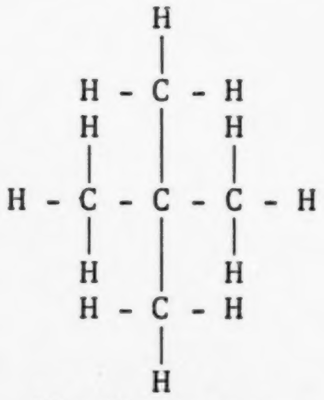
Laboratory Experiences



2 methylbutane

Build models of the first five members of the alkene series.

Supplementary Information



dimethylpropane

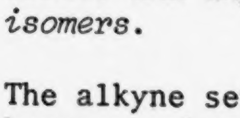
For purposes of examination pupils will be held responsible for the names and formulas for the first five members of the alkane series and their isomers.

The alkene series is also known as the ethylene, or olefin, series.

There are series of hydrocarbons having more than one double bond, such as the dienes. These are not members of the alkene series.

The position of the double bond is shown by a number preceding the name, which indicates the first carbon in the double bond pair.

Topical Outline	Understandings and Concepts	Laborator
	double bonding.	
	Isomerism is shown beginning with the third member of the series, butene. Isomers of the alkenes are named in the same manner as the alkanes.	
3. Alkynes	The alkynes are unsaturated hydrocarbons having one pair of carbon atoms with a triple bond between them. The alkyne series is represented by the general formula C_nH_{2n-2}.	Build mode five membe series.

Understandings and Concepts	Laboratory Experiences	Supplementary Information
ble bonding.		(The carbon atoms are numbered from the end of the chain nearest the double bond.) For example: $CH_3CH_2CH{=}CH_2$ butene or 1-butene (not 3-butene) $CH_3CH{=}CHCH_3$ 2-butene
merism is shown begin- g with the third member the series, butene. mers of the alkenes are ed in the same manner the alkanes.		Example:  $CH_3\overset{CH_3}{\overset{\mid}{C}}H\text{-}CH{=}CH_2$ 3-methyl-1-butene. *Pupils will be held responsible for the names and formulas of the first four members of the alkene series and any of their isomers.*
alkynes are unsaturated rocarbons having one r of carbon atoms with riple bond between them.	Build models of the first five members of the alkyne series.	The alkyne series is also known as the acetylene series.
alkyne series is rep- ented by the general mula C_nH_{2n-2}.		The formula, C_nH_{2n-2}, also represents the alkadienes.

Topical Outline	Understandings and Concepts	Laboratory Experiences
	The alkynes are named by dropping the "-ane" ending of the corresponding alkane and substituting "-yne" to indicate the triple bond.	
	Isomers of alkynes are named in the same manner as the alkenes.	
4. Alkadienes	The alkadienes are unsaturated hydrocarbons having two pairs of carbon atoms with double bonds between them.	Build a model of butadi
	The alkadiene series is represented by the general formula C_nH_{2n-2}.	
	The alkadienes are named by dropping the "-ane" ending of the corresponding alkane and substituting "-adiene" to indicate two double bonds.	

s	Laboratory Experiences	Supplementary Information
ned by " ending ng uting the		The common name for ethyne, C_2H_2, the first member of the alkyne series, is acetylene. The name is still in use and should be familiar to students.
are nanner		*Pupils will be held responsible for the names and formulas of the first three alkynes.*
unsatu- having h atoms between	Build a model of butadiene.	Two double bonds do not occur consecutively in a molecule; that is, one carbon atom cannot form double bonds with two other carbon atoms.
es is general		The alkadienes cannot be distinguished from the alkynes on the basis of their molecular formulas. Butadiene and butyne both have the molecular formula C_4H_6.
named ane" espond- stitut- ndicate		*Pupils will be held responsible for the name and formula of the first member of the alkadiene series, butadiene,* $CH_2=CH-CH=CH_2$.

Topical Outline	Understandings and Concepts	Laboratory Experiences
5. Benzene series	The benzene series is a series of cyclic hydrocarbons which have the general formula, C_nH_{2n-6}.	
	The compound, benzene, is the first member of the benzene series. Other members of the series are named by changing the "-ane" ending of the added alkane radical to "-yl", and adding the word "benzene" to complete the name.	In building a model of methylbenzene, start wi molecules of benzene an methane. This can be u as an introduction to su stitution reactions discussed later.
B. Reactions of hydrocarbons	Hydrocarbons will burn at elevated temperatures.	
	Saturated hydrocarbons are relatively unreactive.	
	Unsaturated compounds are much more reactive than saturated compounds.	

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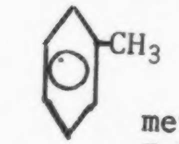
Laboratory Experiences

In building a model of methylbenzene, start with molecules of benzene and methane. This can be used as an introduction to substitution reactions discussed later.

Supplementary Information

Review Area 3, Section IV A 3.

The second member of the benzene series is:



methylbenzene
$C_6H_5CH_3$

The common name for methylbenzene is toluene.

For purposes of examination, only the names and structures for the first two members of the benzene series will be required.

Complete combustion results in the formation of CO_2 and H_2O.

Saturated compounds will react with the halogens (except iodine) to form halogen substitution products.

Topical Outline	Understandings and Concepts	Laboratory Experience
1. Substitution	In a substitution reaction a hydrogen atom is replaced by another kind of atom or group.	Start with a methane m cule and by substituti form (1) trichloromethane, (chloroform)
	Substitution reactions are characteristic of saturated hydrocarbons.	(2) difluorodichlorome ane, CF_2Cl_2 (freon
	Hydrogen atoms of saturated hydrocarbons can be replaced by halogen atoms.	(3) tetrachloromethane CCl_4 (carbon tetra chloride)
	In naming substitution products, use the longest hydrocarbon chain for the alkane's name. Precede this name by prefixes to indicate the kind and number of atoms substituted, and numbers to indicate on what carbons they are located.	

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Laboratory Experiences

Start with a methane molecule and by substitution form

(1) trichloromethane, $CHCl_3$ (chloroform)

(2) difluorodichloromethane, CF_2Cl_2 (freon)

(3) tetrachloromethane, CCl_4 (carbon tetrachloride)

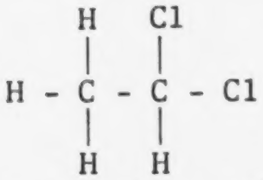
Supplementary Information

In view of the safety aspects, it is recommended that only models be used in working out the organic reactions treated in this section.

Combustion and thermal decomposition are not substitution reactions.

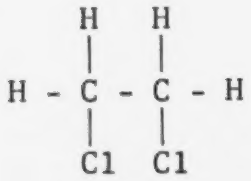
The general term for these substitutions is halogenation, and the products are called halogen derivatives or halogen substitution products.

Examples of substitution products are:



$$\begin{array}{ccccccc} & & H & & Cl & & \\ & & | & & | & & \\ H & - & C & - & C & - & Cl \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

1, 1-dichloroethane



$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & Cl & & Cl & & \end{array}$$

1, 2-dichloroethane

Topical Outline	Understandings and Concepts	Laboratory Experie
2. Addition	Addition reactions are characteristic of unsaturated compounds.	
	Addition usually involves adding one or more atoms at the double bond, resulting in saturation of the bond.	Start with ethylene and "add" hydrogen chlorine atoms to s addition reactions. that ethyne (acetyl can add "more" than
	Generally, addition reactions tend to be faster than substitution reactions.	
	The addition of chlorine and bromine (iodine does not add) may take place at room temperature. The compounds formed are called halogen derivatives.	
	At high temperatures and with suitable catalysts hydrogen can be added at the double bonds. This process is called hydrogenation. The products are saturated compounds.	
	Addition products are named in the same manner as substitution products.	

rstandings Concepts	Laboratory Experiences	Supplementary Information
reactions are istic of unsatu- pounds.		
usually involves e or more atoms uble bond, esult- turation of the	Start with ethylene models and "add" hydrogen or/and chlorine atoms to show addition reactions. Show that ethyne (acetylene) can add "more" than ethene.	Bromine in CCl_4 is used as a test for unsaturation. If this test is used, it should be limited to a teacher demonstration. Bromine can cause serious skin burns. Teachers should acquaint themselves with first aid for bromine burns listed on the reagent's label before performing the experiment.
, addition reac- d to be faster titution reac-		
ion of chlorine ne (iodine does may take place at erature. The com- rmed are called erivatives.		
emperatures and able catalysts can be added at e bonds. This s called hydro- . The products ated compounds.		
products are the same manner tution products.		*Pupils will be held responsible for names and structural formulas of halogen derivatives of hydrocarbons containing no more than five carbon atoms in a straight*

Topical Outline	Understandings and Concepts	Laboratory
3. Polymerization	Polymerization involves the formation of a large molecule from smaller molecules.	Build a pol eral ethyle
	For polymerization to occur, there must be a catalyst and/or increased temperature.	
4. Cracking	Cracking is the process by which long chain molecules can be broken into smaller molecules.	
	Generally, cracking requires the use of a catalyst and increased temperature.	
II. Alcohols		
A. Classes of alcohols	Alcohols can be classified according to the number of -OH functional groups in the molecule: . Monohydroxy alcohols have one -OH group.	A 4.01 is u ducing the the classes

Understandings and Concepts	Laboratory Experiences	Supplementary Information
		chain.
ymerization involves the mation of a large mole- e from smaller mole- es.	Build a polymer from several ethylene models.	Synthetic rubbers, plastics such as polyethylene, and other large chain molecules synthesized by man are polymers. *These polymers are included in optional Area 7.*
polymerization to occur, re must be a catalyst /or increased tempera- e.		
cking is the process by ch long chain molecules be broken into smaller ecules.		The cracking process makes possible a greater yield of usable hydrocarbons for gasoline and other products.
erally, cracking uires the use of a cata- t and increased tempera- e.		*Use sound films to show cracking, polymerization, and fractional distillation processes applied to the production of gasoline.*
ohols can be classified ording to the number of functional groups in molecule:	A 4.01 is useful in introducing the structures of the classes of alcohols.	Methanol (methyl alcohol) and ethanol (ethyl alcohol) are common monohydroxy alcohols.
onohydroxy alcohols have ne -OH group.		In naming monohydroxy alcohols in which the -OH is

Topical Outline	Understandings and Concepts	Laboratory Exper
	. Dihydroxy alcohols have two -OH groups.	
	. Trihydroxy alcohols have three -OH groups.	

Understandings and Concepts

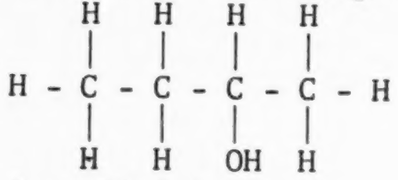
ihydroxy alcohols have wo -OH groups.

rihydroxy alcohols have hree -OH groups.

Laboratory Experiences

Supplementary Information

not attached to an end carbon atom, the position of the -OH group is indicated by a number preceding the name. For example,

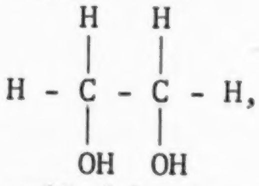


$$\begin{array}{ccccccccc} & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & \\ & & H & & H & & OH & & H & & \end{array}$$

is called 2-butanol.

Dihydroxy alcohols are commonly called glycols.

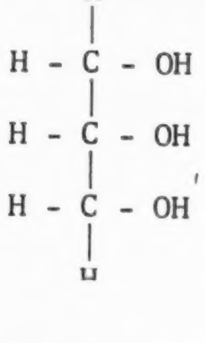
An important dihydroxy alcohol is



$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & OH & & OH & & \end{array}$$

, usually called by its common name, ethylene glycol.

The most important trihydroxy alcohol is glycerol,

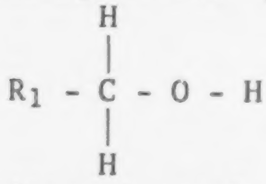


$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & - & C & - & OH \\ & & | & & \\ H & - & C & - & OH \\ & & | & & \\ H & - & C & - & OH \\ & & | & & \\ & & H & & \end{array}$$

Topical Outline	Understandings and Concepts	Laborator

The functional groups of alcohols can be classified as primary, secondary, or tertiary alcohol groups according to the number of carbon chains attached to the carbon having the -OH group.

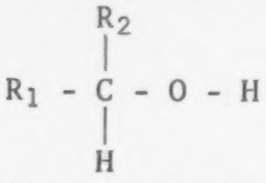
. Primary alcohol group:



$$R_1 - \overset{\displaystyle H}{\underset{\displaystyle H}{C}} - O - H$$

written in condensed structural formulas as $-CH_2OH$.

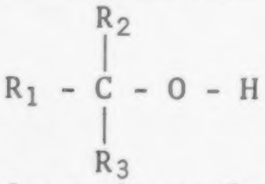
. Secondary alcohol group:



$$R_1 - \overset{\displaystyle R_2}{\underset{\displaystyle H}{C}} - O - H$$

written in condensed structural formulas as -CHOH.

. Tertiary alcohol group:



$$R_1 - \overset{\displaystyle R_2}{\underset{\displaystyle R_3}{C}} - O - H$$

written in condensed

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hol group:

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Laboratory Experiences

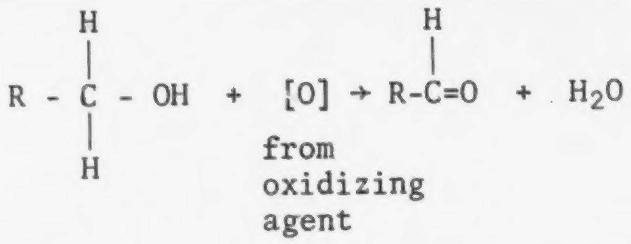
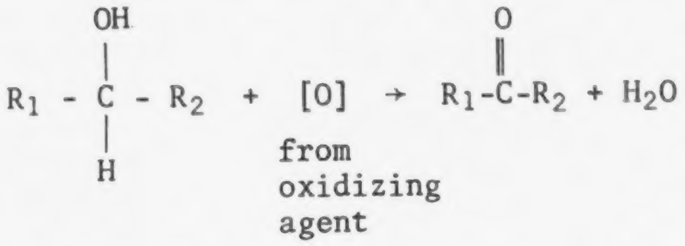
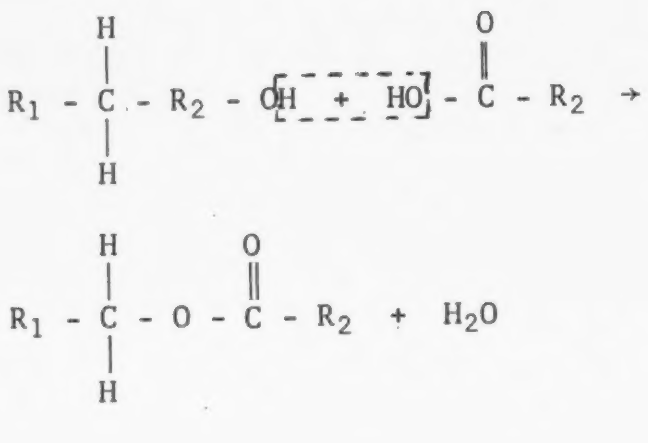
Supplementary Information

Pupils will be held responsible for naming monohydroxy alcohols containing up to five carbon atoms and their straight chain isomers. Pupils will not be expected to name dihydroxy or trihydroxy alcohols except ethylene glycol and glycerol. Pupils will be expected to recognize whether an alcohol is a primary, secondary, or tertiary alcohol from its structural formula.

Topical Outline	Understandings and Concepts	Laboratory Experiences
	structural formulas as -COH.	
	Alcohols show isomerism.	
B. Properties of alcohols	The hydroxyl group gives polarity to some alcohols when H_2O is the solvent.	The solubilities of alc hols are illustrated in A 4.02.
	As the number of hydroxyl groups increases, the more polar the molecule becomes.	
	The -OH functional group in alcohols does not form a hydroxide ion in aqueous solution.	Compare the effect of aqueous alcohol and bas solutions on indicators Account for the differen results.
	Alcohols are electrical nonconductors, even in aqueous solution.	Show the lack of electri conductivity of alcohol such as ethanol and glyc erol.
C. Some reactions of alcohols		
1. Oxidation	Alcohols will burn at elevated temperatures.	Illustrate with an alcoh lamp.

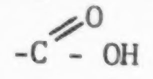
standings Concepts	Laboratory Experiences	Supplementary Information
al formulas as		
how isomerism.		
yl group gives o some alcohols s the solvent.	The solubilities of alcohols are illustrated in A 4.02.	As the length of a hydrocarbon chain increases, the polarity and solubility effects induced by the hydroxyl group are reduced. Monohydroxy alcohols containing a chain of five or more carbon atoms tend to become insoluble.
ber of hydroxyl reases, the more molecule becomes.		Ethylene glycol and glycerol are completely miscible with water.
nctional group s does not form e ion in aqueous	Compare the effect of aqueous alcohol and base solutions on indicators. Account for the different results.	
re electrical non- , even in aqueous	Show the lack of electrical conductivity of alcohols such as ethanol and glycerol.	
ill burn at ele- eratures.	Illustrate with an alcohol lamp.	Complete combustion results in the formation of CO_2 and H_2O.

Topical Outline	Understandings and Concepts	Laboratory Experi
	Primary alcohol groups can be oxidized to aldehydes.	See A 4.03.
	Secondary alcohol groups can be oxidized to ketones.	See A 4.04.
	Tertiary alcohols are not readily oxidized.	
2. Esterification	The hydroxyl group of an alcohol can react with the carboxylic (-COOH) group of an acid to form an ester and water.	The preparation of oil (an ester) is CH 7.17.

ings pts	Laboratory Experiences	Supplementary Information
groups can aldehydes.	See A 4.03.	 $R - \overset{H}{\underset{H}{C}} - OH + \underset{\text{from oxidizing agent}}{[O]} \rightarrow R-\overset{H}{C}=O + H_2O$
hol groups to ketones.	See A 4.04.	 $R_1 - \overset{OH}{\underset{H}{C}} - R_2 + \underset{\text{from oxidizing agent}}{[O]} \rightarrow R_1-\overset{O}{\overset{\|}{C}}-R_2 + H_2O$
ols are not ed.		
roup of an act with the OOH) group form an r.	The preparation of banana oil (an ester) is given in CH 7.17.	 $R_1 - \overset{H}{\underset{H}{C}} - R_2 - O\boxed{H + HO} - \overset{O}{\overset{\|}{C}} - R_2 \rightarrow$ $R_1 - \overset{H}{\underset{H}{C}} - O - \overset{O}{\overset{\|}{C}} - R_2 + H_2O$

Topical Outline	Understandings and Concepts	Laboratory Ex
		A 4.07 illustr fication by th models.
III. Aldehydes	The aldehyde group confers only a moderate polarity to the molecule which tends to make the molecule soluble.	
	Only aldehydes with a low formula mass are soluble in water.	
	Aldehyde groups are very easily oxidized to acids.	The oxidation hyde to an aci trated in A 4.
	Aldehydes can be oxidized by air into their respective acids.	
	Aldehyde groups act as reducing agents.	Heat a few dro aldehyde in Be solution or Feh tion to show th effect of an al See CH 7.14 (a)

	Laboratory Experiences	Supplementary Information
	A 4.07 illustrates esterification by the use of models.	
onfers rity h lecule		As the length of a hydrocarbon chain increases, the tendency to be soluble in water is reduced.
a low uble		
very acids.	The oxidation of an aldehyde to an acid is illustrated in A 4.05.	
dized spec-		
as	Heat a few drops of an aldehyde in Benedict's solution or Fehling's solution to show the reducing effect of an aldehyde. See CH 7.14 (a).	The presence of an aldehyde group is shown by the reduction of the metal ion (usually Cu^{++}) to the metallic state. Benedict's solution is more stable than Fehling's solution.

Topical Outline	Understandings and Concepts	Laborator
IV. Organic Acids	Organic acids contain one or more carboxylic groups having the structure  $-C(=O)-OH$	Using a mo organic ac alkane. A
	The carboxylic group confers considerable polarity to molecules.	
	Organic acids containing one to four carbon atoms are soluble in water.	
	The boiling points of the carboxylic acids are higher than their corresponding hydrocarbons because of the polarity of the molecules.	
	Organic acids react very much like inorganic acids because both produce hydrogen ions in aqueous solution.	
	Organic acids are weak acids.	Compare the some organic some inorgan 7.16 a-d.
	The carboxylic group of acids is very resistant to oxidation.	

rstandings Concepts	Laboratory Experiences	Supplementary Information
cids contain one arboxylic groups e structure OH	Using a model, derive an organic acid from an alkane. A 4.06.	
xylic group con- iderable polarity les.		
cids containing ur carbon atoms le in water.		As the length of the carbon chain of an organic acid increases, the solubility decreases.
ng points of the c acids are higher r corresponding ons because of ity of the mole-		
cids react very inorganic acids oth produce hydro- in aqueous solu-		
cids are weak	Compare the properties of some organic acids with some inorganic acids. CH 7.16 a-d.	
xylic group of very resistant to .		

Topical Outline	Understandings and Concepts	Laborato
	Organic acids react with alcohols to form esters.	See A 4.1
V. Carbohydrates	Carbohydrates can be recognized from an empirical formula written as $C_y(H_2O)_x$.	
	Carbohydrates contain hydroxyl groups and aldehyde or ketone groups.	
A. Monosaccharides	Carbohydrates that cannot be hydrolyzed (reacted with water) into simpler molecules are called monosaccharides.	
	Monosaccharides are known as simple sugars and have the general formula $C_6H_{12}O_6$.	
	In naming classes of monosaccharides, the number of carbon atoms is indicated and the presence of an aldehyde or ketone group is shown by the prefix "aldo" or "keto."	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
rganic acids react with lcohols to form esters.	See A 4.10.	Esters of long chain organic acids (fatty acids) and the alcohol glycerol are fats.
arbohydrates can be recog- ized from an empirical ormula written as $_y(H_2O)_x$.		There is no structural significance to this formula.
arbohydrates contain ydroxyl groups and alde- yde or ketone groups.		
arbohydrates that cannot hydrolyzed (reacted ith water) into simpler olecules are called mono- accharides.		*Pupils are not expected to learn structural formulas of the various carbohydrates but should be acquainted with the functional groups which give rise to the properties of the carbohydrates.*
onosaccharides are known simple sugars and have e general formula $H_{12}O_6$.		
n naming classes of mono- ccharides, the number of rbon atoms is indicated d the presence of an dehyde or ketone group shown by the prefix ldo" or "keto."		Example: A 6-carbon sugar containing an aldehyde group would be called an aldohexose.

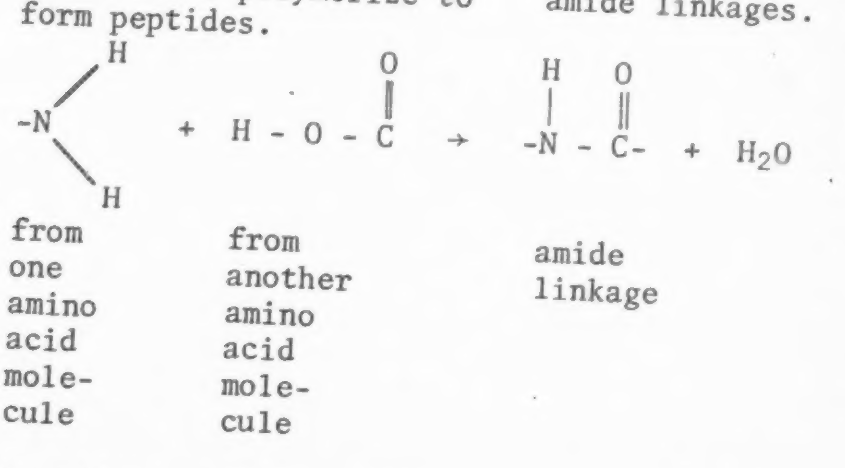
Topical Outline	Understandings and Concepts	Laboratory Experi
	Aldose carbohydrates are reducing sugars.	Show the effect of sugars on Benedict' tion. CH 7.19 a (3
	Glucose and fructose are reducing sugars.	
B. Disaccharides	Carbohydrates that undergo hydrolysis to form two monosaccharide molecules are classified as disaccharides.	
	Cane sugar is a disaccharide known chemically as sucrose, $C_{12}H_{22}O_{11}$. Maltose and lactose are also examples of disaccharides.	Prenursing students have some experienc using a hydrometer the specific gravit sugar solutions.
	The number of polar functional groups present makes the disaccharides soluble in water.	
	In the presence of an acid or the enzyme, invertase, cane sugar can	For the hydrolysis refer to CH 7.19 a

derstandings nd Concepts	Laboratory Experiences	Supplementary Information
carbohydrates are g sugars.	Show the effect of aldose sugars on Benedict's solution. CH 7.19 a (3).	Glucose is an important aldohexose found in fruits, honey, the blood stream, and in other fluids of the body. It is the chief source of energy for the operation of muscles, glands, and nerve impulses.
and fructose are g sugars.		Fructose is the sweetest of all sugars. While it is a ketohexose, it reacts as if it has a "potential" aldehyde group.
drates that undergo sis to form two charide molecules ssified as disac- s.		
gar is a disaccha- own chemically as , $C_{12}H_{22}O_{11}$. and lactose are amples of disaccha-	Prenursing students should have some experiences in using a hydrometer to test the specific gravity of sugar solutions.	
ber of polar func- groups present he disaccharides in water.		
presence of an the enzyme, inver- ane sugar can	For the hydrolysis of sugar refer to CH 7.19 a (4).	The hydrolysis of cane sugar is called inversion of sugar since the mixture

Topical Outline	Understandings and Concepts	Laboratory Exper
	undergo hydrolysis to produce equal amounts of glucose and fructose. The reaction can be expressed: $C_{12}H_{22}O_{11} + H_2O \rightarrow$ $C_6H_{12}O_6 + C_6H_{12}O_6$ glucose fructose	
C. Polysaccharides	The polysaccharides include starch, glycogen (animal starch), and cellulose.	
	Polysaccharides have the general formula $(C_6H_{10}O_5)_x$.	
	Polysaccharides yield many monosaccharide molecules when they are hydrolyzed.	For the hydrolysi starch see CH 7.1
	The large size of the polysaccharide molecule tends to make it insoluble or only slightly soluble in water.	
	The solutions of polysaccharides show colloidal properties.	Use A 5.06 to ill colloidal starch ties.

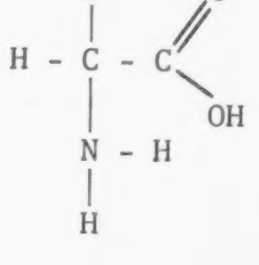
Understandings and Concepts	Laboratory Experiences	Supplementary Information
rgo hydrolysis to pro- equal amounts of glu- and fructose. The tion can be expressed: $C_{12}H_{22}O_{11} + H_2O \rightarrow$ $C_6H_{12}O_6 + C_6H_{12}O_6$ glucose fructose		of products rotates polarized light in the opposite direction from pure sucrose. Glucose and fructose are isomers that have different structures and properties. *The fermentation of sugar is discussed in optional Area 5.*
olysaccharides include ch, glycogen (animal ch), and cellulose.		
accharides have the al formula $_{10}O_5)_x$.		
accharides yield many accharide molecules they are hydrolyzed.	For the hydrolysis of starch see CH 7.19 a (4).	The complete hydrolysis of starch produces glucose.
arge size of the poly- aride molecule tends ke it insoluble or slightly soluble in .		
olutions of polysac- des show colloidal rties.	Use A 5.06 to illustrate colloidal starch properties.	*The colloidal properties of starch solution are treated in optional Area 5.*

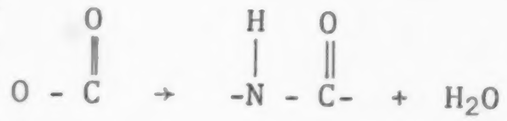
Topical Outline	Understandings and Concepts	Laboratory Exper
VI. Proteins	Proteins are complex nitrogen compounds built up from amino acids.	The protein compo can be qualitativ tigated. Refer t d (1). CH 7.19 d gives a test for
A. Formation from amino acids	An amino acid is an organic compound containing both an amine group (-NH_2) and an organic acid group (-COOH).	
	By forming amide linkages, amino acids polymerize to form peptides.	Activity A 4.09 de amide linkages.


H
-N
H
+ H - O - C
O
→
H O
-N - C-
+ H_2O
from one amino acid molecule
from another amino acid molecule
amide linkage

Peptides, in turn, polymerize to form proteins.

Proteins have very large molecules.

dings epts	Laboratory Experiences	Supplementary Information
omplex nitro- built up ds.	The protein composition can be qualitatively investigated. Refer to CH 7.19 d (1). CH 7.19 d (2) gives a test for proteins.	
is an nd contain- ine group rganic OOH).		Units of amino acids can function as an amine, as an acid, or as both.
de linkages, ymerize to	Activity A 4.09 deals with amide linkages.	An example of an amino acid is glycine. CH_2NH_2COOH, with the structural formula 



$$- O - \overset{\overset{O}{\|}}{C} \rightarrow -\overset{\overset{H}{|}}{N} - \overset{\overset{O}{\|}}{C}- + H_2O$$

m ther no d e- e	amide linkage	
rn, polymer- teins.		*Pupils will be expected to recognize an amino acid from its structural formula, and a peptide from an amide linkage.*
ery large		

Topical Outline	Understandings and Concepts	Laboratory Experiences
B. Hydrolysis	Boiling with dilute acid or the action of certain enzymes can make proteins undergo hydrolysis.	Refer to A 5.03 for the hydrolysis of proteins food.
	The complete hydrolysis of a protein produces amino acids.	
VII. Lipids	Lipids are constituents of plants and animal tissue that are insoluble in water but are soluble in nonpolar solvents.	
	Lipids are esters formed by the reaction between the trihydroxy alcohol, glycerol, and one or more fatty acids.	
	Fatty acids usually have one carboxyl (-COOH) group per molecule. The hydrocarbon chain of the fatty acid is a straight chain containing an even number of carbon atoms.	
	Fatty acids may be saturated or unsaturated.	

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Laboratory Experiences

Refer to A 5.03 for the hydrolysis of proteins in food.

Supplementary Information

The hydrolysis of proteins is treated in optional Area 5.

The term, lipid, will be used in this Section to mean fat or vegetable oil, although some other plant and animal products are included in the lipid group, since they meet the solubility requirements.

The esters of glycerol are sometimes called glycerides.

Some common saturated fatty acids are lauric ($C_{11}H_{31}COOH$), palmitic ($C_{15}H_{31}COOH$), and stearic ($C_{17}H_{35}COOH$).

Topical Outline	Understandings and Concepts	Laboratory Experiences
	Unsaturated fatty acids react like alkenes since the carbon to carbon double bonds will add bromine or hydrogen.	
	Lipids are low-melting-point solids or liquids.	
	The melting point of lipids decreases as the number of double bonds increases.	
	The degree of unsaturation of a natural fat or oil can be reduced to any stage by hydrogenation in the presence of a nickel catalyst.	
	In the presence of enzymes, glycerides can undergo hydrolysis to form three fatty acids and glycerol.	
	The enzymes for the hydrolysis of some glycerides can be furnished by the microorganisms in the air.	

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Laboratory Experiences	Supplementary Information
	Oleic acid ($C_{17}H_{33}COOH$), is an unsaturated fatty acid containing a double bond between the ninth and tenth carbon atoms.
	Lipids which are solids at room temperature are called fats; those which are liquids at room temperature are called oils.
	Hydrolysis of lipids is treated in optional Area 5.

AREA 5 - CHEMISTRY IN THE HO

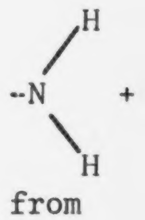
Topical Outline	Understandings and Concepts	Laboratory
I. Foods	Cooking and preservation of foods involve many chemical changes. The preparation of foods changes the structure of their nutrients and/or the texture or particle size of the foods. The most common food nutrients are carbohydrates, proteins, and lipids.	
A. Preservation of food	Preservation of foods is accomplished by preventing the growth of microorganisms which provide the enzymes required for chemical changes in foods. Growth of microorganisms can be controlled by drying, salting, pickling, or irradiation of foods.	
	Heat can be used to destroy microorganisms or to decompose enzymes which bring about changes in foods.	For the effect o the action of th rennin, see A 5.0

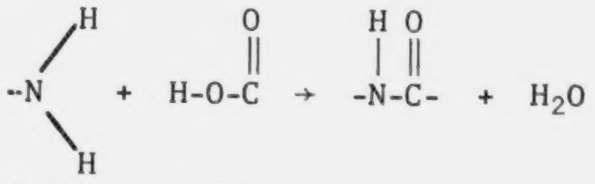
AREA 5 - CHEMISTRY IN THE HOME

nderstandings and Concepts	Laboratory Experiences	Supplementary Information
g and preservation ds involve many al changes.		Two useful resources for this section are Lowe, Belle. *Experimental Cooking.* Fitch, N.K. & Francis, C.A. *Foods and Principles of Cookery.* Prentice-Hall, Inc.
eparation of foods s the structure ir nutrients and/or xture or particle f the foods.		*Teachers should not hesitate to refer to cookbooks as a reference source for this area.* The use of cookbooks will emphasize that there is chemistry involved in the cooking process. Poor cooking results from lack of control of the chemical processes involved in food preparation.
st common food nu- s are carbohydrates, ns, and lipids.		
vation of foods is lished by preventing owth of micro- sms which provide zymes required for al changes in foods.		
of microorganisms controlled by , salting, pickling, adiation of foods.		
an be used to y microorganisms or ompose enzymes bring about changes ds.	For the effect of heat on the action of the enzyme, rennin, see A 5.01.	

Topical Outline	Understandings and Concepts	Laboratory Experiences
B. Some food nutrients		
1. Carbohydrates	Carbohydrates can be recognized from a molecular formula written as $C_y(H_2O)_x$.	
	Most carbohydrates found in foods are sugars and starches.	
a. Sugars	Simple sugars are isomers having the molecular formula $C_6H_{12}O_6$.	Display a collection of different sugars. By referring to the formula on the label have pupils cla sify each as a simple or complex sugar.
	Glucose and fructose are some examples of simple sugars.	
	A complex sugar is formed by the polymerization of two molecules of simple sugars.	
	Sucrose is a complex sugar having the molecular formula $C_{12}H_{22}O_{11}$.	
b. Starches	Starches are polymers of simple sugars.	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
hydrates can be rec- ed from a molecular la written as $0)_x$.		There is no structural significance to this formula.
carbohydrates found ods are sugars and hes.		
e sugars are isomers g the molecular la $C_6H_{12}O_6$.	Display a collection of different sugars. By referring to the formula on the label have pupils classify each as a simple or a complex sugar.	
se and fructose are examples of simple s.		Fructose is much sweeter than glucose.
plex sugar is formed e polymerization of olecules of simple s.		Maltose and lactose are examples of complex sugars.
se is a complex sugar g the molecular for- $C_{12}H_{22}O_{11}$.		Sucrose is also known as cane sugar or table sugar.
hes are polymers of e sugars.		

Topical Outline	Understandings and Concepts	Laboratory Experiences
	The molecular formula for a starch is $(C_6H_{10}O_5)_n$.	
2. Proteins	Proteins are complex nitrogen compounds built up from amino acids.	The protein composition can be qualitatively investigated. Refer to CH 7.19 d (1). CH 7.19 d (2) gives a test for proteins. A 4.09 deals with amide linkages.
	An amino acid is an organic compound containing both an amine group ($-NH_2$) and an organic acid group ($-COOH$). Proteins have very large molecules.	 from one amino acid
3. Lipids	Fats and oils are classified as lipids. Fats and oils are esters of long chain fatty acids and glycerol.	Compare the solubility of lipids in different solvents.
a. Saturated	If the long chain of the lipid contains only single bonded carbon atoms, the fat is saturated.	

Laboratory Experiences	Supplementary Information
The protein composition can be qualitatively investigated. Refer to CH 7.19 d (1). CH 7.19 d (2) gives a test for proteins. A 4.09 deals with amide linkages.	By forming amide linkages, amino acids polymerize to form peptides.  $-N(H)(H) + H-O-\overset{O}{\overset{\Vert}{C}} \rightarrow -\overset{H}{\overset{\vert}{N}}-\overset{O}{\overset{\Vert}{C}}- + H_2O$ from one amino acid — from another amino acid — an amide linkage
Compare the solubility of lipids in different solvents.	Constituents of plant and animal tissues that are insoluble in water but are soluble in nonpolar solvents are known as lipids.
	Vegetable oils have a greater degree of unsaturation than animal fats. At room temperatures, vegetable oils are liquids while animal fats are solids.

Topical Outline	Understandings and Concepts	Laboratory Experiences
b. Unsaturated	Unsaturated lipids contain double bonds between some adjacent carbon atoms.	
C. Changing structure of nutrients		
1. Hydrolysis	A reaction between a nutrient and water is called hydrolysis.	
a. Carbohydrates	Carbohydrates undergo hydrolysis during the cooking process. In the presence of an acid or the enzyme, invertase, cane sugar can undergo hydrolysis to produce equal amounts of glucose and fructose. The reaction can be expressed: $C_{12}H_{22}O_{11} + H_2O \rightarrow$ sucrose $C_6H_{12}O_6 + C_6H_{12}O_6$ glucose fructose	For the hydrolysis of suga refer to CH 7.19 a(4).

ndings cepts	Laboratory Experiences	Supplementary Information
ipids contain between some on atoms.		The degree of unsaturation of natural fat or oil can be reduced by hydrogenation in the presence of a nickel catalyst. Oleomargarines and solid vegetable shortenings are made by hydrogenating a liquid vegetable oil.
tween a nu- ter is ysis.		Hydrolysis can also be defined as the reaction of any species with water.
s undergo uring the ess.	For the hydrolysis of sugar refer to CH 7.19 a(4).	The hydrolysis of cane sugar is called inversion of sugar since the mixture of products rotates the polarized light in the opposite direction from pure sucrose.
nce of an acid e, invertase, an undergo o produce s of glucose . The re- e expressed: H_2O → $H_{12}O_6$ ructose		

Topical Outline	Understandings and Concepts	Laboratory Experien
	As the concentration of the hydrolysis products increases, the boiling point of the solution increases.	The "stages" of boil syrup can be used to sure" the amount of sugar. See A 5.02.
	As the concentration of hydrolysis products increases, the density of the solution increases.	
	Starches undergo hydrolysis to form simple sugars.	Benedict's solution used to detect the p of a simple sugar in *boiled* starch soluti
b. Proteins	Proteins undergo hydrolysis when boiled with dilute acid or when in the presence of certain enzymes.	Use A 5.03 to show hy ysis of food protein
	During hydrolysis a protein molecule breaks up into several smaller molecules.	
	Meat tenderizers contain enzymes that promote hydrolysis.	
c. Lipids	In the presence of enzymes from microorganisms in air, lipids can undergo hydrolysis.	

erstandings d Concepts	Laboratory Experiences	Supplementary Information
ncentration of lysis products , the boiling the solution in-	The "stages" of boiling syrup can be used to "measure" the amount of simple sugar. See A 5.02.	Prenursing students should have some experiences in using a hydrometer to test the specific gravity of sugar solutions.
ncentration of s products in- the density of ion increases.		
undergo hydrolysis imple sugars.	Benedict's solution can be used to detect the presence of a simple sugar in a *boiled* starch solution.	
undergo hydrolysis ed with dilute hen in the of certain en-	Use A 5.03 to show hydrolysis of food proteins.	Collagen, the protein found in connective tissues and ligaments. hydrolyzes in boiling water to form gelatin.
drolysis a pro- cule breaks up ral smaller mol-		The complete hydrolysis of a protein produces amino acids.
erizers contain hat promote s.		
esence of enzymes oorganisms in air, n undergo hydrol-		

Topical Outline	Understandings and Concepts	Laboratory Experi
	During hydrolysis a lipid molecule may form products which have a disagreeable odor and taste.	
2. Oxidation	Atmospheric oxygen reacts with unsaturated lipids to produce malodorous products. The enzymes from microorganisms in the air are catalysts for the oxidation of lipids.	
3. Coagulation	Heating causes the globular proteins in egg white and milk to coagulate. The enzyme, rennin, and dilute acids can also coagulate the globular proteins in milk.	Coagulation of pro illustrated in A 5,
D. Changing texture or particle size	Gluten protein chains are formed when doughs are beaten or kneaded.	A 5.05 is concern the coagulation of in flours and the affecting gluten c mation.

erstandings d Concepts	Laboratory Experiences	Supplementary Information
drolysis a lipid nay form products e a disagreeable taste.		One of the hydrolysis products of butter is butyric acid. Very slight amounts of the acid can be detected because of its disagreeable odor.
ic oxygen reacts turated lipids to alodorous prod-		Lipids become rancid as a result of hydrolysis and/or oxidation.
es from micro- in the air are for the oxida- ipids.		Keeping butter and other fats and oils covered and in a cool place reduces the possibility of hydrolysis and oxidation and retards the onset of rancidity.
auses the globular in egg white and oagulate.	Coagulation of proteins is illustrated in A 5.04.	Cottage cheese is made by the coagulation of milk proteins.
e, rennin, and di- s can also coagu- globular proteins		Commercial casein glues are made from milk proteins.
otein chains are en doughs are kneaded.	A 5.05 is concerned with the coagulation of gluten in flours and the factors affecting gluten chain formation.	By controlling the amount of gluten formation, the texture of the dough can be controlled.

Topical Outline	Understandings and Concepts	Laboratory Experienc
1. Colloidal dispersions	A colloid is a mixture containing particles which are larger than those in a solution but smaller than those in a true suspension.	Use CH 3.46 to illust the intermediate posi of colloidal particle
	A colloid contains a dispersed substance in a dispersing medium.	
	The phases of the two parts of a colloid may be alike or different.	
a. Kinds of colloids	A gel contains a liquid suspended in a solid.	Use CH 3.49 to illus types of colloids.
	A sol contains a solid suspended in a liquid.	Ask pupils to make a lection or a list of colloids used as foo
	An emulsion is a suspension of two immiscible liquids.	
	A sponge is a gas dispersed in a solid.	
	A foam is a gas suspended in a liquid.	
	A fog is a liquid suspended in a gas.	

gs s	Laboratory Experiences	Supplementary Information
ixture con- s which are e in a so- er than suspension.	Use CH 3.46 to illustrate the intermediate position of colloidal particles.	
ns a dis- in a dis-		
e two parts be alike		A colloid may not be made by dispersing a gas in another gas. The combination would be a gaseous solution.
a liquid solid.	Use CH 3.49 to illustrate types of colloids.	
a solid sus- uid.	Ask pupils to make a collection or a list of some colloids used as foods.	
a suspension le liquids.		The size of the suspended particles determines the stability of an emulsion.
as dispersed		
suspended		
id suspended		The "steam" coming from containers in which food is being cooked is really a fog of tiny particles of condensed water suspended in air.

Topical Outline	Understandings and Concepts	Laboratory Experie
	Smoke contains a solid dispersed in a gas.	
b. Properties of colloids	Colloids have some properties of a solution and some properties of a suspension.	Compare the appeara tling rate, and abi pass through a filt $FeCl_3$ solution and loidal dispersion. CH 3.46.
	Colloidal suspensions show the Tyndall effect.	Demonstrate the Tyn effect by use of CH
2. Forming gels	A cooling starch solution sets to a gel.	The colloidal prope a starch suspension illustrated by use A 5.06.
	The proteins in a gelatin-water dispersion will form a gel upon being chilled.	
3. Forming emulsions	The long hydrocarbon chains found in lipid molecules make them insoluble in water.	A 5.07 deals with t solubility of lipid

dings epts	Laboratory Experiences	Supplementary Information
s a solid a gas.		
some prop- olution and es of a sus-	Compare the appearance, settling rate, and ability to pass through a filter of a $FeCl_3$ solution and a colloidal dispersion. See CH 3.46.	
pensions show ffect.	Demonstrate the Tyndall effect by use of CH 3.53.	
rch solution .	The colloidal properties of a starch suspension can be illustrated by use of A 5.06.	Upon heating, the starch granules in a suspension swell and form a viscous solution with colloidal properties. The starch in flour, cornstarch, and tapioca can absorb great quantities of liquid as the gel is formed; these substances are used as thickening agents.
in a gelatin- ion will form ing chilled.		
ocarbon in lipid e them in- ter.	A 5.07 deals with the insolubility of lipids.	

Topical Outline	Understandings and Concepts	Laboratory Experiences
	Immiscible lipids can be permanently suspended by "coating" the drops with a substance (called an emulsifying agent) that is compatible with both liquids.	A 5.08 illustrates the emulsifying action of eg and starch.
	Reducing the size of suspended liquid particles makes an emulsion more stable.	
4. Leavening action	Leavening agents form a gas which expands upon being heated and changes the texture of the dough.	Finding a combination of chemicals that will produce a leavening effect the problem in A 5.09.
	Baking powder, baking soda, yeast, and steam are common leavening agents.	

erstandings d Concepts	Laboratory Experiences	Supplementary Information
ble lipids can be ntly suspended by g" the drops with ance (called an fying agent) that is ble with both .	A 5.08 illustrates the emulsifying action of eggs and starch.	Flour, cornstarch, and egg yolk are emulsifying agents used in the preparation of gravy and salad dressings.
		The role of the emulsifier is similar to the detergent effect discussed in more detail in Section III A of this Area.
g the size of sus- liquid particles n emulsion more		Homogenized milk is made by using ultrasonic waves to break up the butter fat globules into particles small enough to stay dispersed in the skim milk.
ng agents form a ch expands upon be- ted and changes the of the dough.	Finding a combination of chemicals that will produce a leavening effect is the problem in A 5.09.	Early recipes used brandy for the leavening agent. The steam formed in the dough produced the main leavening effect. The lower boiling point of alcohol allowed it to escape before the dough "cooked."
powder, baking soda, and steam are common ng agents.		Dry baking powders contain sodium bicarbonate (baking soda) and tartaric acid, or acid salts such as monocalcium phosphate and disodium phosphate. When water

Topical Outline	Understandings and Concepts	Laboratory Experiences
	The reaction between an acid or acid salt and sodium bicarbonate is the basis for the leavening action of baking powder and baking soda.	
		The role of proteins in leavening is shown in A 5.10.
	Yeast produces enzymes which cause the fermentation of sugar. $C_6H_{12}O_6 \xrightarrow{\text{enzyme}} 2CO_2 + 2C_2H_5OH$	Many laboratory manuals contain directions for experiments on fermentation.

standings Concepts	Laboratory Experiences	Supplementary Information
		is added, the acid or acid salt ionizes and reacts with the sodium bicarbonate to form CO_2 gas.
ion between an cid salt and so- rbonate is the the leavening baking powder and da.		
		The lactic acid in sour milk reacts with the baking soda to form CO_2 gas.
	The role of proteins in leavening is shown in A 5.10.	Many cakes, biscuits, and breads require the use of baking powder as the leavening agent.
		The large number of eggs used in making sponge cake and cream puffs produces strong gluten chains and a "tough" dough which can keep the steam trapped.
oduces enzymes use the fermenta- sugar. nzyme $2CO_2 + 2C_2H_5OH$	Many laboratory manuals contain directions for experiments on fermentation.	The large amount of CO_2 produced from the fermentation process provides a leavening action for breads and rolls.
		The spoilage of some foods is caused by undesirable fermentation processes.

Topical Outline	Understandings and Concepts	Laboratory Experience
5. Crystallization	When a sugar crystal or a piece of foreign matter is introduced into a supersaturated sugar solution, the excess dissolved sugar in the solution begins to crystallize.	
	The size of sugar crystals determines the texture of a candy.	Controlling crystal gro in candy is treated in A 5.11.
	Crystals formed in sugar syrup, honey, or maple syrup can be dissolved by heating the substance.	
II. Home Cleaning and Sanitation	Cleansing requires the loosening or dissolving of fats and oils which bind dirt to surfaces.	
	Sanitation requires the control of bacteria, mold, and virus growth which may endanger the health of the individual.	
	Water alone is not a good cleaning agent, since it is a polar solvent and grease is nonpolar.	

ings pts	Laboratory Experiences	Supplementary Information
rystal or a gn matter is o a super- r solution, solved sugar n begins to		
gar crystals texture of	Controlling crystal growth in candy is treated in A 5.11.	Candy making depends upon (1) hydrolysis of cane sugar, and (2) the control of crystal growth from the resulting supersaturated solution.
d in sugar or maple issolved by bstance.		Generally, supersaturated sugar solutions such as honey are quite stable. When crystallization does occur, the solution is reformed easily.
ires the issolving of which bind es.		
uires the teria, mold, th which may ealth of the		
not a good , since it is t and grease		

Topical Outline	Understandings and Concepts	Laboratory Experien
A. Soaps and detergents	Soaps and detergents are composed of complex molecules which enable water to mix with oil or grease.	
	The molecules of a soap or detergent consist of a long hydrocarbon-like "tail" and a very polar, water soluble "head." The "tail" is soluble in the grease films, and the "head" is soluble in water.	Use soap to emulsify ture of kerosene "oi water.
1. Soaps	Soaps are metallic salts of fatty acids having a chain consisting of 10 to 18 carbon atoms.	CH 7.19-c(4) may be for an activity invo saponification.

tandings oncepts	Laboratory Experiences	Supplementary Information
detergents are f complex mole- h enable water h oil or grease.		When water containing a detergent or soap is put on a grease film, the "tails" of the soap or detergent molecules dissolve in the grease. At the same time the "heads" are attracted to the water. As a result, the film is loosened, and tiny globules of oil, from which the polar ends of the soap or detergent project, are formed. The polar ends give the surface of the oil globules a charge and set up a stable emulsion.
les of a soap or consist of a long n-like "tail" polar, water ead." The "tail" in the grease the "head" is water.	Use soap to emulsify a mixture of kerosene "oil" and water.	
metallic salts cids having a isting of 10 to atoms.	CH 7.19-c(4) may be used for an activity involving saponification.	Common soaps are sodium or potassium salts of stearic or palmitic acids. While the sodium salts are more widely used, the potassium soaps are softer and more soluble.

Topical Outline	Understandings and Concepts	Laboratory Exper
	Soaps react with minerals in hard water to form a "scum."	
	Soaps are made by reacting a fat and aqueous NaOH or KOH.	
	fat + base → a soap + glycerol	
	The reaction for making a soap is called saponification.	
2. Detergents	Detergents are sodium salts of long chain alkyl sulfates (sulfonates).	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
Soaps react with minerals in hard water to form a "scum." Soaps are made by reacting a fat and aqueous NaOH or KOH. fat + base → a soap + glycerol The reaction for making a soap is called saponification.		The reaction for making a typical soap, sodium stearate, from beef fat (glyceryl stearate) and sodium hydroxide is: $C_3H_5(OOC(CH_2)_{16}CH_3)_3$ $3NaOH \rightarrow 3CH_3(CH_2)_{16}COONa +$ $C_3H_5(OH)_3$ *For purposes of examination, pupils will not be held responsible for the formulas for substances involved in saponification.* Grease that collects in drain pipes can be removed by saponification. Drain cleansers are very caustic and care must be taken in using them. They can corrode the plumbing pipes and produce serious burns on the skin. Be sure to follow directions listed on the container.
Detergents are sodium salts of long chain alkyl sulfates (sulfonates).		Detergents are also known as syndets.

Topical Outline	Understandings and Concepts	Laboratory Experiences
	Detergents which can be decomposed by bacteria are known as biodegradable detergents.	
	Biodegradable detergents in present use are straight chain alkyl sulfates.	
B. Bleaching	Bleaching is accomplished by the oxidation or reduction of coloring agents.	
	Bleaching by oxidation involves the addition of oxygen to the coloring agent, while bleaching by reduction involves the removal of oxygen from the coloring agent.	
	Laundry bleaches form hypochlorous acid which decomposes to form oxygen which, in turn, combines with the coloring agent.	Bleaching by oxidation i illustrated by CH 4.24-b

derstandings nd Concepts	Laboratory Experiences	Supplementary Information
nts which can be osed by bacteria own as biodegradable nts.		Early detergents such as lauryl sulfonate (sulfate) created a sewage problem because soil bacteria were not able to break down the detergent molecule and destroy its sudsing effect.
radable detergents sent use are straight lkyl sulfates.		
ing is accomplished oxidation or reduc- f coloring agents.		
ing by oxidation in- the addition of to the coloring while bleaching by ion involves the re- of oxygen from the ng agent.		The composition of the coloring agent determines which bleaching action should be used.
y bleaches form hypo- us acid which decom- to form oxygen which, n, combines with the ng agent.	Bleaching by oxidation is illustrated by CH 4.24-b.	*The disinfecting action of chlorine bleaches is discussed under Section C - hypochlorites of this area.*
		Pupils should be warned that a chlorine bleach in the presence of a strong soap, household ammonia, or an acid such as a vinegar solution forms poisonous chlorine

Topical Outline	Understandings and Concepts	Laboratory Experienc
	Peroxide bleaches decompose to form oxygen which reacts with the coloring agent.	
	Reducing bleaches make use of a combination of sulfur dioxide and moisture which removes oxygen from the coloring agent.	A reducing bleach ca illustrated by the r between oxalic acid tassium permanganate
	The effect of a reducing bleach is counteracted by prolonged exposure to air.	
	The type of material to be bleached determines the strength of the bleach to be used: . Chlorine bleaches are strong bleaches which tend to destroy fibers. . Peroxide bleaches and the sulfur dioxide-water bleach are considered to be mild bleaches.	For the effect of bl on fibers see A 5.12

erstandings d Concepts	Laboratory Experiences	Supplementary Information
		gas. When using a chlorine bleach, one should follow the directions listed on the label.
e bleaches decompose oxygen which reacts e coloring agent.		The 7% H_2O_2 solution on the market is primarily a bleaching product and too strong an oxidizing agent to be used as an antiseptic.
g bleaches make use mbination of sulfur , and moisture which oxygen from the g agent.	A reducing bleach can be illustrated by the reaction between oxalic acid and potassium permanganate.	Oxalic acid is often used to remove stains. Oxalic acid is poisonous.
ect of a reducing is counteracted by ed exposure to air.		The yellowing of white wool or straw is caused by oxygen from the air reacting with the material.
e of material to be d determines the h of the bleach to	For the effect of bleaches on fibers see A 5.12.	
rine bleaches are ng bleaches which d to destroy fibers.		Chlorine destroys protein fibers.
xide bleaches and sulfur dioxide-water ch are considered to ild bleaches.		

Topical Outline	Understandings and Concepts	Laboratory Experiences
	Bleaching of yellow materials may be accomplished by the use of a bluing agent.	Compare the appearance under a yellow light of piece of white cloth an a similar piece of whit cloth which has been dip into a weak laundry blu solution.
C. Disinfectants	A disinfectant is an agent that will destroy the cell structure or enzymes of bacteria.	Discover materials that be used as disinfectant See A 5.13.
	A disinfectant used for cleaning should be able to concentrate on, adhere to, and sterilize a surface and keep it resistant to bacterial growth.	Evaluate the effectivene of disinfectants on bacterial growth. See A 5.

ndings ncepts	Laboratory Experiences	Supplementary Information
f yellow y be accom- he use of a nt.	Compare the appearance under a yellow light of a piece of white cloth and a similar piece of white cloth which has been dipped into a weak laundry bluing solution.	This illustrates a physics principle that a mixture of yellow and blue reflected light forms a complementary mixture that appears to be white.
nt is an agent estroy the cell r enzymes of	Discover materials that can be used as disinfectants. See A 5.13.	An ideal disinfectant is nonspecific in its germicidal action, nontoxic, harmless to human tissue, and remains effective in hard or saline water or in contact with organic matter.
nt used for ould be able ate on, adhere rilize a sur- ep it resis- terial growth.	Evaluate the effectiveness of disinfectants on bacterial growth. See A 5.18.	Many disinfectants are insoluble in water, but form emulsions in soap or detergent solutions. The higher coal tar phenols are carcinogenic and are unsuitable for use as disinfectants.

AREA 6 - ENVIRONMENTAL POLLUTION

Topical Outline	Understandings and Concepts	Laboratory Experienc
I. Introduction	A pollutant is a substance found in the environment which normally is lacking, or, if naturally occurring, is found in greater than normal concentrations.	
	Pollutants may be natural or man-made.	
	Contamination of our environment has increased to a point that it is a serious threat to the health and economic welfare of society.	
	In the past, man has depended on dilution and natural purification processes to control pollution.	
	Factors which contribute to the increasing contamination of the environment are the population explosion, the growth of industrial processes, the growth of large urban	

AREA 6 - ENVIRONMENTAL POLLUTION

rstandings Concepts	Laboratory Experiences	Supplementary Information
ant is a substance the environment rmally is lacking, aturally occurring, in greater than oncentrations.		
ts may be natural ade.		Natural pollutants include pollen, dust, silt, and microbes. Manmade pollutants include sewage, pesticides, industrial wastes, and automotive emissions.
ation of our en- t has increased to that it is a threat to the nd economic wel- society.		The rate at which man adds pollutants to the environment is so great that some authorities estimate that the total amount of pollution in the world doubles every 10 years.
ast,man has de- n dilution and purification pro- o control pollu-		Man can no longer depend upon natural processes for pollution control.
which contribute ncreasing contam- of the environment population explo- e growth of in- processes, the f large urban		

Topical Outline	Understandings and Concepts	Laboratory Experi
	centers close to each other, and the desire for an ever higher standard of living.	
	The first important requirement of a pollution control program is an aroused community of informed citizens and officials.	
	Pollutants may be found in water, in air, and/or on land. A particular activity of man may cause pollution in all three areas.	
II. Water		
A. Water supply	Man obtains most of his water from surface water and ground water.	

ngs ts	Laboratory Experiences	Supplementary Information
to each desire for standard		
rtant re- pollution n is an ity of in- s and		Discuss the role of the individual and of local, State, and Federal governments in controlling pollution. Legislators, lawyers, public health officials, and sanitary engineers are good resource people for class visitations, either in person or via tape.
be found in and/or on cular n may cause ll three		People in their daily living activities add pollutants to the environment when they drive automobiles, heat their homes, discharge sewage, dispose of refuse, etc.
st of his face water er.		Surface water includes lakes, rivers, streams, and reservoirs. Ground water is water naturally found beneath the surface of the earth.

Topical Outline	Understandings and Concepts	Laboratory Experiences
	The total amount of water on earth remains relatively constant. Water is continually circulating through a cycle of precipitation, runoff, infiltration, storage, evaporation, and reprecipitation called the water cycle.	A terrarium can be used t illustrate the natural wa cycle. If a terrarium is unavailable, a sealed plastic bag containing a little water can be used show the processes of evaporation and condensation.
	The water from a major river can be used many times as it flows from the source of the river to its mouth. The only practical solution to a shortage of fresh water is more reuse of the same water.	
	When water from precipitation and "returned" ground water are not added to the water table at the same rate that they are removed, the depth of water in the table decreases and a water shortage may occur.	
B. Naturally occurring substances in the water supply		
1. Rainwater	Naturally occurring substances found in rainwater include fine particles of salt, dust, and smoke which served as condensation nuclei. The	

of water
relative-
er is
lating
f precip-
infiltra-
aporation,
on called

major
many
from the
er to its
practical
rtage of
re reuse
.

recipita-
ed" ground
ed to the
e same
e re-
of water
eases and
may occur.

ng sub-
rainwater
icles of
smoke
condensa-
e

Laboratory Experiences

A terrarium can be used to illustrate the natural water cycle. If a terrarium is unavailable, a sealed plastic bag containing a little water can be used to show the processes of evaporation and condensation.

Supplementary Information

The demand for fresh water has been increasing. Some surveys indicate a shortage of fresh water in the future. The population of the United States increased two and one-half times from 1900 to 1960, but the use of water per day increased four times for the general population, seven times for agriculture, and eleven times for industry.

The lowering of the water table in some parts of the country is a matter of great concern.

Traces of ozone, nitrogen oxides, argon, sulfur dioxide, ammonia, and other gases may be present in rainwater.

Topical Outline	Understandings and Concepts	Laboratory Experience
	principal gases from the air dissolved in rainwater are oxygen, nitrogen, and carbon dioxide.	
	Most rainwater is weakly acidic because of the carbon dioxide dissolved in it.	Test the pH of rainwat
2. Ground water	When weakly acidic rainwater falls upon the earth, more carbon dioxide is taken up as the water infiltrates the soil, flows in streams, and/or is stored. Substances that dissolve in weak acids are leached by the ground water. This reduces the acidity and increases the concentration of minerals in the water.	Test the pH of ground
	Water containing ions of calcium, magnesium, and/or iron is called hard water.	Compare the number of of "standard" soap sol needed to produce suds samples of water from different sources.
	Hard water renders soap ineffective as a cleaning agent.	Soap solutions can be "standardized" by comp the number of drops ne to produce suds in distilled water.

	Laboratory Experiences	Supplementary Information
the nwater , and		
akly e lved in	Test the pH of rainwater.	The pH value of rainwater ranges from 5.5 to 6.0.
ain- earth, is r in- flows s that ds are d the s the erals	Test the pH of ground water.	Ground water containing weak alkaline materials may have a pH range of 8.0 to 8.5.
s of and/ rd	Compare the number of drops of "standard" soap solution needed to produce suds in samples of water from different sources.	The number of drops of standard soap solution necessary to produce suds is a rough measure of the degree of hardness in water.
oap aning	Soap solutions can be "standardized" by comparing the number of drops needed to produce suds in distilled water.	*Students may encounter the unit parts per million (p.p.m.). The unit is used to express small concentrations of substances in water without using fractions.*

Topical Outline	Understandings and Concepts	Laboratory E
		Evaporate wat different sou compare the a residue. Ign residues. In residues will Organic resid
		Demonstrate t ability to co electricity i measuring the tion of disso
C. Water pollutants		
1. Sewage	Sewage is water carrying human, animal, or organic wastes from homes, industrial establishments, or other places.	
	Sewage contains human and animal body discharges, household wastes, street washings, ground water, infiltration, and industrial wastes.	A 6.01 may be detect oil in washings.
	Bacterial action causes the decomposition of organic matter.	

	Laboratory Experiences	Supplementary Information
	Evaporate water from different sources and compare the amount of residue. Ignite the residues. Inorganic residues will not char. Organic residues will char.	*1.0 p.p.m. = 1 mg./liter* *1 liter water = 1,000,000 mg. water* *1 p.p.m. = 1 mg./1,000,000 mg. water*
	Demonstrate that the ability to conduct electricity is a way of measuring the concentration of dissolved minerals.	
rrying rganic indus- ts, or		Fresh sewage is a turbid liquid containing organic and inorganic "solids" which may be dissolved, suspended, or floating.
man and rges, street ater, indus-	A 6.01 may be used to detect oil in street washings.	Organic solids include animal and plant waste products, dead animal matter, plant tissue, and synthetic organic materials such as soaps, detergents, frothing agents, and grease.
		Inorganic matter in sewage includes sand, grit, gravel, silt, and mineral salts.
auses the rganic		The bacteria may use organic matter for food and decompose it into simpler substances.

Topical Outline	Understandings and Concepts	Laboratory Exper
	Aerobic bacteria require dissolved oxygen for their metabolism whereas anaerobic bacteria do not require oxygen.	
	As the concentration of aerobic bacteria increases, the amount of oxygen used by the bacteria increases, and the amount of available dissolved oxygen in the water decreases.	The determination dissolved oxygen involves a simple tion as described
	Decomposition products from aerobic bacteria do not give the water an offensive appearance or putrid odor.	
	As aerobic decomposition proceeds, the dissolved oxygen level may decrease to a point where anaerobic conditions develop.	
	The anaerobic decomposition forms a dark, putrid smelling sludge.	An aquarium in whic large amount of dec matter is present m used to illustrate malodorous gases ar formed.

gs s	Laboratory Experiences	Supplementary Information
a require n for their eas an- a do not		
ation of a increases, xygen used increases, of avail- oxygen in ases.	The determination of dissolved oxygen (DO) involves a simple titration as described in A 6.02.	Low oxygen content can kill fish and other plant and animal life.
roducts cteria do ter an rance or		
mposition issolved y decrease e anaerobic lop.		
ecomposi- rk, putrid .	An aquarium in which a large amount of decaying matter is present may be used to illustrate that malodorous gases are formed.	H_2S, a decomposition product, may be responsible for the putrid odor present during the anaerobic stage.

Topical Outline	Understandings and Concepts	Laborator
	Biochemical oxygen demand (BOD) refers to the quantity of dissolved oxygen utilized in the biochemical oxidation of organic matter in a specified time and at a specified temperature. It is a measure of the organic matter in waste waters which will undergo decomposition by microorganisms. Other organisms in addition to bacteria may remove dissolved oxygen from water. Also, certain chemical wastes discharged into water will undergo reactions removing oxygen from water. A high BOD test for a sample of water indicates that sewage may be present in the water, but it is not conclusive proof.	The 5-day BC described ir
2. Infectious agents	Sewage contains many microorganisms which may include pathogenic bacteria and viruses from infected hosts. These may enter the sewage by way of intestinal body wastes.	

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Laboratory Experiences

The 5-day BOD test is described in A 6.03.

Supplementary Information

The BOD test is one of the principal tests applied to sewage. Generally, a sample of water is taken and its dissolved oxygen content immediately determined. Another sample of the water is taken at the same time, sealed, and held at 20° C. for 5 days. After the fifth day, its dissolved oxygen content is determined. The decrease in dissolved oxygen is called the biochemical oxygen demand for the 5 days; the BOD is expressed in mg./l (p.p.m.) of sample. When a 5-day BOD test is made on polluted water, it is usually necessary to dilute the sample being tested to prevent all of the oxygen in the sealed sample from being used up before the end of the test.

Parasitic bacteria which produce toxic or poisonous compounds that can cause diseases in the host are known as pathogenic bacteria.

Topical Outline	Understandings and Concepts	Laboratory Experiences
	An index for aquatic pollution is the concentration of E. coli, a nonpathogenic bacterium of the intestine.	Kits are commercially available that include materials and instructions for finding a coliform count by the membrane filter technique.
	Standards for public water supplies have been set by the U.S. Public Health Service. These standards provide definite minimums as to the number of samples examined and also the maximum number of coliform organisms allowable per 100 ml. of water.	

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Laboratory Experiences

Kits are commercially available that include materials and instructions for finding a coliform count by the membrane filter technique.

Supplementary Information

Typhoid fever, endemic diarrhea, dysentery, and infectious hepatitis may be transmitted by a water supply polluted by improperly treated sewage.

Pathogenic bacteria are difficult to detect but are often intestinal associates of E. coli. The assumption is that as long as E. coli are present, there is a chance that some pathogenic bacteria are also present.

> Warning! Handle all bacterial cultures as if the organisms they contain are pathogenic. Incinerate them promptly after use.

The threat posed by infectious agents to human health is reflected in numerous beach closings across the country. In 1967, out of 83 beaches along the southern shore of Lake Erie, 27 were unsafe for swimming for the whole season, and 28 only periodically safe.

Topical Outline	Understandings and Concepts	Laboratory Experi
3. Heat	Heat is added to a waterway as water from industrial cooling processes is returned to the waterway at a higher temperature.	
	Increasing the temperature of a waterway is known as thermal pollution.	
	As the temperature of a waterway increases, the maximum content of dissolved oxygen decreases.	Let a glass of cold set overnight. Obs the bubbles that co on the glass as som the dissolved gases out of solution bec of the increased te ture of the water.
		Have students find level of samples of at different temper and compare their r with figures listed solubility tables f reference books.
	Heat affects the life processes of organisms living in water and interferes with the decomposition of wastes.	

tandings oncepts	Laboratory Experiences	Supplementary Information
dded to a water- ter from indus- ling processes ed to the water- higher temper-		Large quantities of fresh water are used for cooling by the Nation's industries.
g the temperature rway is known as ollution.		Major contributors to thermal pollution are steel plants, fossil-fuel electrical plants, and nuclear reactors.
mperature of a increases, the ontent of dis- ygen decreases.	Let a glass of cold water set overnight. Observe the bubbles that collect on the glass as some of the dissolved gases come out of solution because of the increased temperature of the water.	
	Have students find the DO level of samples of water at different temperatures and compare their results with figures listed in solubility tables found in reference books.	
ts the life of organisms water and in- ith the decom- f wastes.		The growth of most algae is increased by an increase in the temperature of the water.
		Some game fish can survive only in cool streams; if the stream temperature is raised, these die off and are replaced by less desirable species.

Topical Outline	Understandings and Concepts	Laboratory Experiences
4. Sediments	Silt, mud, and dust have always been water and air pollutants.	A 6.04 describes the settleable solids test.
	By exposing the surface of the earth to erosion, man has become responsible for increasing the siltation of waterways.	
	The oldest and largest bulk pollutant is silt.	
	Silt can eventually destroy a water course. Silt can also affect the types of life in the water.	Evaporate and ignite the residue from silty water to show silt is mostly inorganic matter.
5. Radioactive substances	Most radioactive wastes produced are associated with the production of electricity by nuclear reactors.	
	The total quantity of radioactive wastes produced yearly is increasing.	
	High-level radioactive wastes which are considered too dangerous to be released to the environment are concentrated and stored for long periods of time before disposal.	

erstandings d Concepts	Laboratory Experiences	Supplementary Information
mud, and dust have been water and air ants.	A 6.04 describes the settleable solids test.	During the thirties, American farms annually lost half a million acres of topsoil from wind and water erosion in the Dust Bowl. Similar losses have occurred in the world as a result of exposing savannahs and jungles to erosion.
osing the surface of rth to erosion, man come responsible for sing the siltation erways.		
dest and largest bulk ant is silt.		
an eventually destroy r course. Silt can ffect the types of n the water.	Evaporate and ignite the residue from silty water to show silt is mostly inorganic matter.	An excess of silt causes fish to die.
adioactive wastes ed are associated the production of icity by nuclear rs.		The mining, milling, and preparation of fuel for reactors and weapons produce wastes containing natural radioisotopes.
tal quantity of ctive wastes produced is increasing.		Irradiation within the reactor produces wastes rich in fission products.
level radioactive which are considered ngerous to be re- to the environment ncentrated and for long periods of efore disposal.		The necessity of storing radioactive liquid wastes in tanks for hundreds of years has led planners within industry to consider converting these wastes into solids for burial. Possible burial sites include salt mines and spaces cut deep into bedrock.

Topical Outline	Understandings and Concepts	Laboratory Ex
	Radioactive wastes of low activity are released directly into the air or into waterways. These processes are carefully controlled.	
	Radioisotopes are released into the environment by fallout from nuclear tests conducted in the atmosphere. These fallout products can be concentrated by plants and animals in food chains.	Samples of soi leached by wat water examine of radioactivi background lev A 7.21.
	Exposure to radiation from radioisotopes ingested into the body is much more dangerous than exposure to radiation outside the body.	Irradiated see purchased and of the irradia the seeds exa A 7.20.
6. Minerals and chemical substances	Detergents, fertilizers, insecticides, pesticides, and other industrial chemical wastes are appearing in our water sources.	Compare the r by evaporatio samples taken drinking sour ately pollute a heavily pol Ignite the re test for the organic and i matter.

rstandings Concepts	Laboratory Experiences	Supplementary Information
tive wastes of low y are released y into the air or terways. These es are carefully led.		
otopes are released e environment by from nuclear tests ed in the atmos- These fallout s can be concen- by plants and in food chains.	Samples of soil can be leached by water and the water examined for levels of radioactivity above background levels. See A 7.21.	In a study of the lichen-caribou-Eskimo food chain, the concentration of radioactive cesium-137 was six times greater in the Eskimo than in the lichen.
e to radiation from otopes ingested e body is much more us than exposure ation outside the	Irradiated seeds can be purchased and the effects of the irradiation upon the seeds examined. See A 7.20.	Reindeer moss concentrates radioisotopes from fallout which, in turn, are transferred to reindeer as they graze. In 1965, it was reported that Laplanders, who eat reindeer, had reached the highest radiation exposures of any population.
nts, fertilizers, cides, pesticides, er industrial l wastes are ng in our water .	Compare the residues left by evaporation of water samples taken from a drinking source, a moderately polluted stream, and a heavily polluted stream. Ignite the residues to test for the presence of organic and inorganic matter.	

Topical Outline	Understandings and Concepts	Laboratory Expe
	Stable chemicals may build up to a concentration which is harmful to man when he drinks the water.	
	Plants and animals may concentrate chemicals in their tissues. When man uses the plants for food, he ingests the chemicals in harmful quantities.	
	Some chemicals change the pH of water and may affect the growth of organisms in the water or the corrosiveness of the water.	Compare the corro nail by distilled and by water samp low or high pH va
	Chemicals which can be decomposed by bacteria are known as soft or biodegradable substances.	
a. Plant nutrients	Agricultural chemicals are washed or leached off farm land into waterways.	
	Chemicals may accelerate the growth of some organisms and upset the balance of nature.	
	Eutrophication is the aging of a lake from an aquatic condition to a semiterrestrial or fully terrestrial state. This aging process	

Laboratory Experiences	Supplementary Information
	The dangers from many chemicals lie in their cumulative effect.
	Dangerous concentrations of mercury and fluoride compounds from industrial wastes and pesticides have been found in aquatic organisms.
Compare the corrosion of a nail by distilled water, and by water samples having low or high pH values.	
	Phosphate fertilizer washed into a water course may accelerate the growth of algae. The growth of the algae upsets the balance of nature to the extent that a pond may be destroyed or a beach ruined.

Topical Outline	Understandings and Concepts	Laboratory Experien
	is largely a result of enrichment by nutrients.	
	In many bodies of water, the natural process of eutrophication has been accelerated to a considerable degree by pollution.	
b. Pesticides	For many years, large quantities of pesticides have been used in agriculture. Some of these are extremely harmful to man, if ingested. Many are nonbiodegradable. These pesticides leach into the ground and wash into waterways. Like the radioactive pollutants, they can be concentrated in food chains.	Activities involving layer chromatography detection of some of insecticides and pest are described in the chromatography texts in Appendix B under A
	Varying amounts of some pesticides have been found widespread in water supplies.	
	Some pesticides contain fluorine and yield fluoride ions after degradation.	A test for the fluori ion is described in A

	Laboratory Experiences	Supplementary Information
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ater, of been nsider- ution.		
ge cides gri- hese ul to Many e. ach wash ke the nts, rated	Activities involving thin layer chromatography for detection of some of the insecticides and pesticides are described in the chromatography texts listed in Appendix B under Area 8.	
some n		Adult trout in Lake George showed a high concentration of DDT. It did not kill the adult fish, but it did halt reproduction (many eggs did not hatch, and, if they did, the fish did not live beyond the fry stage).
tain de-	A test for the fluoride ion is described in A 6.05.	The long-range effects of pesticides upon the health of the general population is being investigated by public health authorities.

Topical Outline	Understandings and Concepts	Laboratory Exper
	Pesticides vary in their degree of toxicity and in their biodegradability. In general, the chlorinated pesticides are most resistant to biodegradation and are highly toxic to aquatic life. The organic pesticides that contain phosphorus are less toxic to aquatic life and are more biodegradable. The carbamate group is noted for low toxicity to aquatic life and high biodegradability.	
c. Industrial chemicals	Acids, bases, and sulfur compounds are among the industrial chemicals that contaminate waterways.	Determine the DO c a sample of water. add a small amount Na_2SO_3 (a chemical might appear in in wastes). Stir, an mine the DO conten water again. Note lower DO value due oxidation of sulfit
	Organisms are sensitive to changes in pH.	Germinate seeds (Se A 7.20) in solution varying pH. Soak t first, and then kee moistened with weak tions of vinegar or hold ammonia cleane Compare the rate of nation and the growt seedlings with a gro controls.

tandings oncepts	Laboratory Experiences	Supplementary Information
es vary in their f toxicity and in odegradability. al, the chlorinated es are most resis- iodegradation and ly toxic to aquatic he organic pesti- at contain phos- re less toxic to life and are more dable. The carba- up is noted for city to aquatic high biodegrad-		Pesticides are grouped into three categories: inorganic, natural organic, and synthetic organic compounds. Major types of synthetic organics are those that contain: - chlorine (DDT, endrin, lindane) - phosphorus (parathion, malathion) - carbamate (captan, sevin, ferbam).
ases, and sulfur s are among the in- chemicals that ate waterways.	Determine the DO content of a sample of water. Then add a small amount of Na_2SO_3 (a chemical which might appear in industrial wastes). Stir, and determine the DO content of the water again. Note the lower DO value due to the oxidation of sulfite ions.	Industrial chemicals may be added directly to the waterway or indirectly through the community sewage system.
s are sensitive es in pH.	Germinate seeds (See A 7.20) in solutions of varying pH. Soak them first, and then keep them moistened with weak solutions of vinegar or household ammonia cleaner. Compare the rate of germination and the growth of seedlings with a group of controls.	Other chemical pollutants include preservatives, antioxidants, thickeners, thinners, moisteners, emulsifiers, and coloring agents.

Topical Outline	Understandings and Concepts	Laboratory Experiences
d. Salt water	Sea water seeps inland when the ground water removed from the soil exceeds the amount replaced by precipitation.	
	Small amounts of salts carried in water may accumulate on land due to continual evaporation and cause serious losses in agricultural productivity.	Try to germinate seeds using a saline solution that approximates the concentration of sea water.
e. Detergents	A major problem with detergents as pollutants is that their phosphate content is thought to hasten eutrophication of waterways.	A 6.06 may be used to illustrate the effect of detergents on algal growth.

ings epts	Laboratory Experiences	Supplementary Information
eps inland ind water the soil amount re- ecipitation.		During a recent drought period, the water supply in parts of Long Island was contaminated with salt water. If sufficient precipitation occurs, enough fresh water will soak into the ground so that the net flow through the ground toward the sea prevents the entry of sea water into the ground reservoir.
of salts ter may land due to poration and losses in productivity.	Try to germinate seeds using a saline solution that approximates the concentration of sea water.	Excessive irrigation practices may lead to high concentrations of salt if the irrigation water is lost primarily by evaporation rather than by percolation into the soil.
lem with pollutants phosphate ought to phication of	A 6.06 may be used to illustrate the effect of detergents on algal growth.	The first detergents were branched chain benzene sulfonates. The bacteria would "eat" the chain until the branch was met. Then the bacterial action would stop. Since the remaining chains were sufficiently long to keep the detergent properties, the "sudsing" effect was noticeable in the water supply. All detergents manufactured today are biodegradable.

Topical Outline	Understandings and Concepts	Laboratory Experiences
f. Oil	A pollutant of our waterways and oceans is oil.	
	Accidents at sea may cause oil pollution.	
	Oil will not sink nor dissolve in water.	Demonstrate the immiscibility of oil and water.
	Crude oil slicks cannot be destroyed by fire.	Pour a little heavy motor oil representing crude oil over some water in a beaker, and show that it will not continue to burn when set on fire.
D. Self-purification	Water can "purify itself" of natural pollutants.	
	Self-purification is dependent upon time, temperature, oxygen supply, and other environmental factors which regulate biological growth.	

	Laboratory Experiences	Supplementary Information
		Certain concentrations of alkyl benzene sulfonate have been found to kill mayfly larvae and reduce shrimp and crayfish populations.
water- oil.		Outboard engines discharge oily exhausts into waterways; oil tankers often pump their sludge overboard.
ay cause		The Liberian oil tanker, Torrey Canyon, in March of 1967, lost most of her 36 million gallons of oil into the sea. Fish and sea birds died by the thousands and resort beaches were contaminated.
nor dis-	Demonstrate the immiscibility of oil and water.	
annot be	Pour a little heavy motor oil representing crude oil over some water in a beaker, and show that it will not continue to burn when set on fire.	
itself" nts.		Some waterways are so heavily polluted that natural purification processes are unable to produce clear water.
is de- tem- upply, nental late		

Topical Outline	Understandings and Concepts	Laboratory Experi
	Self-purification of a stream is generally considered to take place in four stages with the stream divided into four zones which merge into each other.	
1. Degradation	The zone of degradation occurs immediately below the point of pollution. The dissolved oxygen in the water decreases. Aerobic decomposition of sewage is prevalent.	
2. Decomposition	The zone of decomposition is characterized by anaerobic decomposition. Dissolved oxygen is very low and may reach zero.	
3. Recovery	In the zone of recovery, the dissolved oxygen increases, and the number of microorganisms in the stream decreases.	
4. Clean water	In the clean water zone, the decomposition of organic solids is mostly complete. Oxygen is at or near the saturation point.	

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Laboratory Experiences

Supplementary Information

When a heavy load of sewage is received, the stages of purification may require many miles of streambed before the process is complete.

In the zone of degradation, the stream becomes turbid with visible floating and suspended solids. The fish life decreases.

In the zone of decomposition, foul odors are produced as products of the anaerobic decomposition. Fish life is absent. If the pollution load of the stream is light enough, this stage of self-purification may not appear.

In the zone of recovery, the number of bacteria decreases as conditions for rapid growth become less favorable.

Topical Outline	Understandings and Concepts	Laboratory Expe
E. Water treatment	The methods used in the treatment of water depend, to a large extent, upon the purpose for which the water is to be used.	Field trips to th water and/or sewa ment plants can p useful learning e for pupils.
	Most of the water treatment processes may be applied to sewage treatment.	
	All water treatment plants, whether designed to remove sewage or produce potable water, have devices to remove or cut up the larger suspended or floating materials.	
	Primary treatment for sewage involves the removal of suspended solids by the physical process of sedimentation in settling tanks. Chemicals may be added which improve the sedimentation process.	
	In secondary treatment plants, the water containing sewage remaining after primary treatment is pumped to "trickling filters" where biochemical decomposition occurs.	

dings epts	Laboratory Experiences	Supplementary Information
used in the water depend, xtent, upon for which the be used.	Field trips to the local water and/or sewage treatment plants can provide a useful learning experience for pupils.	A representative of the Public Health Service, water works, or sewage plant is usually available to talk with the pupils at school.
water treat- es may be ewage treat-		
eatment plants, gned to re- or produce r, have de- ove or cut up uspended or erials.		In preliminary treatment, some devices in common use are screens, grinders, and grit chambers.
tment for ves the re- pended solids cal process tion in set- Chemicals which improve ation process.		Physical separation by sedimentation removes 40-60 percent of the suspended solids. If chemicals are added, 80-90 percent of the suspended solids are removed. Primary treatment may reduce the BOD by 25 to 30 percent.
treatment water con- ge remaining y treatment "trickling ere biochemical n occurs.		Secondary treatment is comparable to the zone of recovery in the self-purification of a stream. Bacterial films form on the surfaces of the rocks or tiles used in the "trickling filter," and it is there that the decomposition takes place.

Topical Outline	Understandings and Concepts	Laboratory Experiences
	Tertiary treatment plants improve still more the effluent before discharge.	
1. Aeration	Aeration is the spraying of water into the air.	
	Aeration introduces oxygen into the water, permits the escape of dissolved gases such as CO_2 and H_2S, and removes volatile substances which may cause undesirable taste and odor.	Use A 6.07 to show that aeration increases the amount of dissolved air in water. Add a few drops of universal indicator to some carbonated soda water. Bubble air through the water or pour it from one container to another so CO_2 can escape. Note the effect on the pH as CO_2 escapes.
2. Adsorption of gases	Activated charcoal has the ability to adsorb great quantities of gases and volatile liquids to its surface.	Use A 6.08 to illustrate removing odors by adsorption.
3. Coagulation and sedimentation	Suspended particles that are more dense than water and large enough to be affected by the pull of gravity will settle upon standing.	Use the Tyndall effect to show the presence of colloidal materials in tap water.

erstandings d Concepts	Laboratory Experiences	Supplementary Information
ry treatment plants e still more the nt before discharge.		Some tertiary plants remove nutrients when algal growth in the discharge water is a particular problem.
on is the spraying er into the air.		Aeration may be a process used in any sewage treatment plant.
on introduces oxygen e water, permits cape of dissolved uch as CO_2 and H_2S, oves volatile ces which may cause able taste and	Use A 6.07 to show that aeration increases the amount of dissolved air in water. Add a few drops of universal indicator to some carbonated soda water. Bubble air through the water or pour it from one container to another so CO_2 can escape. Note the effect on the pH as CO_2 escapes.	Reducing the CO_2 content reduces the corrosive tendency of water. Control of taste and color by aeration is limited.
ed charcoal has lity to adsorb uantities of gases atile liquids to face.	Use A 6.08 to illustrate removing odors by adsorption.	Charcoal is used in fish tanks as well as municipal water supplies to remove dissolved gases. In both cases, aeration must follow to replace the oxygen removed along with the other gases.
ed particles that e dense than water ge enough to be afy the pull of grav- l settle upon stand-	Use the Tyndall effect to show the presence of colloidal materials in tap water.	Colloidal particles will not settle readily on standing.

Topical Outline	Understandings and Concepts	Laboratory Experiences	S
		Prepare colloidal suspensions containing varying amounts of clay. Show that the amount of coagulant necessary to remove the suspended material depends upon the turbidity.	E s m p o t
		Use suspensions of equal turbidity, but varying pH, to show that the amount of coagulant required depends upon the pH of the suspension.	
4. Chlorination	Chlorine may be added to water for the purpose of disinfection.		D o h m a
	As water is reused on an increasing scale, the variety and concentration of contaminants in the water supply which are not affected by chlorination increases.		S t n a t e
	Chlorine may be added to water in the form of a gas or in compounds such as calcium hypochlorite or sodium hypochlorite.		C t h d c i
	Water with high pH value is difficult to disinfect.		H c 6

ngs ts	Laboratory Experiences	Supplementary Information
	Prepare colloidal suspensions containing varying amounts of clay. Show that the amount of coagulant necessary to remove the suspended material depends upon the turbidity.	Electrolytes and coagulants, such as aluminum sulfate, may be used to coagulate particles so they settle or can be filtered out of the suspension.
	Use suspensions of equal turbidity, but varying pH, to show that the amount of coagulant required depends upon the pH of the suspension.	
added to purpose n.		Disinfection is the killing of the larger portion of the harmful and objectional microorganisms in, or on, a medium.
used on an le, the ncentration s in the hich are chlorina-		Some public health authorities suspect that contaminants in drinking water which are not affected by chlorination may have long-range effects upon the population.
added to orm of a ounds such ochlorite chlorite.		Chlorine combines with water to form hypochlorous and hydrochloric acids. When dissolved in water, hypochlorites yield hypochlorite ions.
n pH value o disinfect.		Hypochlorous acid dissociates at pH levels below 6.

Topical Outline	Understandings and Concepts	Laboratory Experi
	Chlorine reacts with many compounds in sewage. Little disinfection results from this action. The amount of chlorine used by both organic and inorganic substances is defined as the chlorine demand.	
	Disinfection is caused mostly by the amount of chlorine remaining (residual chlorine) after the chlorine demand has been satisfied.	Determination of re chlorine by titrati described in A 6.09 colorimetric method scribed in the *Stan Methods* text listed the bibliography.
5. Water softening	Minerals causing hardness in water are removed by using precipitation or ion-exchange methods to remove Ca^{++} and Mg^{++}.	
	Precipitation is achieved by the use of lime (CaO) or (Na_2CO_3).	

ings pts	Laboratory Experiences	Supplementary Information
ts with many sewage. ection results ion. The orine used ic and in- ances is de- chlorine		Nitrates, manganese, iron, and H_2S react with and remove chlorine. Ammonia reacts with chlorine to form chloramines, which have less disinfecting qualities than free chlorine.
is caused amount of ining (resid-) after the nd has been	Determination of residual chlorine by titration is described in A 6.09. A colorimetric method is described in the Standard Methods text listed in the bibliography.	Chlorine may destroy bacterial cells directly or kill bacteria indirectly by inactivating their enzymes. The temperature of the water and the length of time Cl_2 remains in the water affect the disinfecting reaction rate.
ing hardness removed by tation or methods to nd Mg^{++}.		The ion-exchange method has become the primary treatment.
is achieved lime (CaO)		Lime reacts with $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ to produce insoluble carbonates. Soda ash is anhydrous sodium carbonate. It reacts with Ca^{++} and Mg^{++} to form insoluble carbonates.

Topical Outline	Understandings and Concepts	Laboratory Experie
	The buildup of scale from hard water in hot water pipes and boilers is a problem of both homeowners and industrial firms.	
	A base or basic salt, such as borax or trisodium phosphate, can be used for the precipitation of the metallic bicarbonates from hard water: $HCO_3^- + OH^- \rightarrow H_2O + CO_3^=$ $CO_3^= + Ca^{++} \rightarrow CaCO_3$	
	Ion-exchange materials replace the calcium and magnesium ions by other cations that do not affect the cleansing action of soap.	In the laboratory, mi tures of acid-exchang resins and base-excha resins may be used to remove metallic and n metallic ions from wa to produce demineral water.

	Laboratory Experiences	Supplementary Information
le from water is a meowners ms.		Homeowners who use hard water spend more money for soap per year than if their water were soft.
lt, such ium sed for of the tes		
$CO_3^=$		
O_3		
ials m and other t af- action	In the laboratory, mixtures of acid-exchange resins and base-exchange resins may be used to remove metallic and nonmetallic ions from water to produce demineralized water.	Home water softeners generally use zeolite or Permutit to replace the calcium and magnesium ions by sodium ions. The zeolite or Permutit softeners can be recharged by flushing with a solution of sodium chloride. An ion-exchange substance may be either a complex sodium-silico-aluminate or an organic polymer resin which replaces calcium and magnesium ions with sodium or hydrogen ions that do not affect the cleansing action of soap.

Topical Outline	Understandings and Concepts	Laboratory Experien
III. Air		
A. Composition of the air	Under "normal conditions" the atmosphere is composed of approximately 79 percent nitrogen, 20 percent oxygen, and 1 percent of a variety of gases including water vapor, carbon dioxide, and inert gases.	
B. Causes of air pollution	Most air pollution results from combustion, vaporization, or division of matter into small particles which are emitted as dusts and mists.	

dings epts	Laboratory Experiences	Supplementary Information
		The high sodium content of some water softened by deionization may be a health problem for some people.
l conditions" re is com- roximately itrogen, 20 en, and 1 per- riety of gases ter vapor, de, and inert		Since air is a mixture, its percentage composition is not fixed.
lution results ion, vaporiza- ision of small parti- re emitted as sts.		A major source of pollution is the burning of fuels to produce electricity, steam, energy for propelling vehicles, and heat to warm buildings and carry on industrial processes.
		Many industries produce vapors from the evaporation of solvents and fumes from manufacturing and refining processes.
		Industries which crush, grind, mix, cut, and spray materials almost always emit clouds of dust or mist into the air.

Topical Outline	Understandings and Concepts	Laboratory
C. Some major air polluters		
1. Industry	Our industrial complex is an important source of air pollution.	
2. Internal combustion engines	Air pollution from automobiles, trucks, and buses creates the most serious air pollution problems for many cities.	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
r industrial complex is important source of r pollution.		Steam generating plants; quarries and cement plants; metal-fabricating, chemical, and petrochemical plants; and refineries are among the industrial facilities which produce air pollution.
r pollution from auto- biles, trucks, and buses eates the most serious r pollution problems for ny cities.		The number of motor vehicles in this country is increasing at a faster rate than the population. In addition to water and carbon dioxide, when 1,000 gallons of gasoline are burned in the average automobile, about 3,200 pounds of carbon monoxide, 200 to 400 pounds of hydrocarbons, 25 to 75 pounds of oxides of nitrogen, 18 pounds of aldehydes, and 17 pounds of oxides of sulfur are produced. Ozone and lead compounds are also produced. Altogether, some 150 chemicals have been found in automobile exhaust, including benzopyrene, a potent cancer-producing agent.

Topical Outline	Understandings and Concepts	Laboratory Expe
3. Furnaces and incinerators	Householders add to air pollution when they heat their homes and burn rubbish and leaves in backyard incinerators.	
D. Air pollutants	A number of air sampling stations have been established throughout the country to sample and measure air pollutants.	For the effect of pollution on nylo A 6.10.
1. Solids	Solids such as dust, metal particles, and ashes are air pollutants.	Use the fume hood trate the charact of a smoke tested A 6.11.
	The smoke coming from an industrial or home chimney or burning cigarette, cigar, or pipe is a colloidal dispersion of a solid in a gas. There may be other products in addition to the solids in the smoke from these sources.	Observe dust part air by using A 6. Investigating the ness of air is de in A 6.13. Collection of win particles is desc A 6.14. The amount of dus a location may be See A 6.15.

derstandings and Concepts	Laboratory Experiences	Supplementary Information
holders add to air tion when they heat homes and burn rub- and leaves in back- incinerators.		Smoking, as a personal source of air pollution, adds CO, hydrocarbons, oxides of nitrogen, and other compounds to the air.
ber of air sampling ons have been estab- d throughout the ry to sample and re air pollutants.	For the effect of air pollution on nylon, see A 6.10.	Measured volumes of air are drawn through large filters which catch and hold solid particles and liquid droplets. Air is also drawn through solutions which absorb specific gases.
s such as dust, metal cles, and ashes are ollutants.	Use the fume hood to illustrate the characteristics of a smoke tested in A 6.11.	
oke coming from an trial or home chimney rning cigarette, , or pipe is a col- l dispersion of a in a gas. There other products in ion to the solids in oke from these s.	Observe dust particles in air by using A 6.12. Investigating the cleanliness of air is described in A 6.13. Collection of windblown particles is described in A 6.14.	The burning of garbage, trash, and rubbish, and the burning of leaves in incinerators are prime sources of the fine suspended particles of dust, soot, and other solids in air.
	The amount of dustfall in a location may be measured. See A 6.15.	Suspended solids soil houses and clothing, and can irritate eyes.

Topical Outline	Understandings and Concepts	Laboratory Exper
2. Liquids	Liquids such as hydrocarbons, oils, tars, and organic solvents pollute the air.	Use A 6.16 to illu pollution of the a
	Liquids may exist in air as aerosols.	A 6.17 can be use out the effect of pollution on plan
	An aerosol is a colloidal dispersion of a liquid in a gas.	
3. Gases	Common gas pollutants of air are sulfur dioxide, carbon monoxide, hydrogen sulfide, oxides of nitrogen, hydrocarbons, carbon dioxide, and ozone.	
a. Carbon monoxide	Carbon monoxide is produced by the incomplete combustion of a carbon fuel.	The laboratory bu be used to illust complete and inco combustion.
	Carbon monoxide reduces the oxygen-carrying capacity of the blood.	
b. Oxides of nitrogen	Nitrogen oxides are produced by burning coal, oil, gasoline, and some rocket fuels.	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
iquids such as hydro- arbons, oils, tars, and rganic solvents pollute he air.	Use A 6.16 to illustrate pollution of the air.	Aerosol sprays, hydrocarbons in automobile exhaust and from dry cleaning plants, and evaporation of paint solvents are some of the sources of liquid pollutants. The exhaust of jet engines forms an oil aerosol.
iquids may exist in air s aerosols.	A 6.17 can be used to point out the effect of oil pollution on plants.	
n aerosol is a colloidal ispersion of a liquid in gas.		While a colloidal suspension of a solid in a gas may be considered to be an aerosol, generally it is called a smoke.
ommon gas pollutants f air are sulfur dioxide, arbon monoxide, hydrogen ulfide, oxides of ni- rogen, hydrocarbons, arbon dioxide, and ozone.		
arbon monoxide is pro- uced by the incomplete ombustion of a carbon uel.	The laboratory burner can be used to illustrate complete and incomplete combustion.	
arbon monoxide reduces he oxygen-carrying apacity of the blood.		
itrogen oxides are pro- uced by burning coal, il, gasoline, and some ocket fuels.		

Topical Outline	Understandings and Concepts	Laboratory Experiences
	Nitrogen oxides contribute to smog formation.	
	Smogs are formed when there is a high production of pollutants and a stagnant airmass over the area for an extended period of time.	Details for constructin a temperature inversion apparatus can be found references listed in th bibliography.
	Smog formation is often associated with the occurrence of air inversions.	
	Smog products are irritating to the eyes and induce respiratory diseases.	
c. Gaseous sulfur compounds	Gaseous sulfur compounds are produced by burning coal, oil, and leaves.	See A 6.18 for a method measuring the content o SO_2 in the air.
		A measure of the relati acidity of an air sampl is described in A 6.19.

nderstandings nd Concepts	Laboratory Experiences	Supplementary Information
gen oxides contrib- o smog formation.		Photochemical pollution is a name given to smog formation. The sunlight causes a reaction between the oxides of nitrogen and hydrocarbons. The resulting products may be more harmful than the original pollutants.
are formed when there high production of tants and a stagnant ss over the area for tended period of time.	Details for constructing a temperature inversion apparatus can be found in references listed in the bibliography.	
formation is often iated with the occur- of air inversions.		An air inversion occurs when colder air underlies warmer air and prevents normal convection currents from operating.
products are irri- g to the eyes and in- respiratory diseases.		
us sulfur compounds roduced by burning oil, and leaves.	See A 6.18 for a method of measuring the content of SO_2 in the air.	H_2S and SO_2 can affect the paint on our homes. H_2S is also 2 1/2 times as poisonous as CO and similar to HCN in the degree of toxicity.
	A measure of the relative acidity of an air sample is described in A 6.19.	

Topical Outline	Understandings and Concepts	Laboratory Expe
d. Hydrocarbons	Unburned hydrocarbons are found in the exhaust of vehicles.	
E. Prevention of air pollution	The best method of preventing air pollution is to remove pollutants at their source and prevent their introduction into the air.	
	Solid particles can be made to settle from air by electrostatic methods.	For construction c electrostatic prec see A 6.20.
	Low-boiling-point substances can be condensed by lowering their temperatures.	Pass steam throug condenser to illus condensation of a
	Pollutants with acid properties can be neutralized with bases.	
	Pollutants with basic properties can be neutralized with acids.	

ings pts	Laboratory Experiences	Supplementary Information
rocarbons are exhaust of		Volatile hydrocarbons are components of fuels such as gasoline and diesel fuel. When spilled, these fuels evaporate quickly.
hod of pre- pollution is llutants at and prevent uction into		
les can be le from air atic methods.	For construction of an electrostatic precipitator, see A 6.20.	The particles are given an electric charge and then are attracted to an oppositely charged plate.
point sub- be condensed their tempera-	Pass steam through a water condenser to illustrate condensation of a gas.	Sometimes a pressure change is used in addition to reduced temperature. Mercury vapors which are dangerous to health are condensed by means of high condensing towers.
ith acid prop- e neutralized		
ith basic prop- e neutralized		

Topical Outline	Understandings and Concepts	Laboratory Experien
	Excess water vapor can be removed by deliquescent substances.	Use calcium chloride example of a deliques substance.
	Soot can be burned completely to form CO_2.	Use A 6.21 to illustr "after burning."
	Soluble substances in the air can be removed by water and other solvents.	
	Gases can be adsorbed on activated charcoal.	
	Some automobiles are equipped to have greater air intake and/or exhaust recycling systems to help attain better combustion of the exhaust gases.	
	Fuels that have a lower sulfur content can be burned in specially designed burners.	
	Covering surfaces of volatile materials will cut down evaporation.	

ndings ncepts	Laboratory Experiences	Supplementary Information
er vapor can be deliquescent	Use calcium chloride as an example of a deliquescent substance.	
e burned com- form CO_2.	Use A 6.21 to illustrate "after burning."	It is an economic advantage to burn carbon fuels completely.
stances in the removed by ther solvents.		
e adsorbed on harcoal.		
biles are have greater and/or exhaust ystems to help er combustion ust gases.		Pupils will probably be familiar with the federal requirements set for exhaust control on automobiles. Continual research is being done to improve or find a substitute for the internal combustion engine.
have a lower ent can be pecially de- ers.		
rfaces of vol- ials will cut ation.		

Topical Outline	Understandings and Concepts	Laboratory Experiences
IV. Land	Ashes, garbage, abandoned cars, septic tank residues, chemicals, and trash of all kinds are among the solid wastes which need continuous disposal.	See A 6.22 for an activi involving the biodegradability of solids.
	The disposal of millions of tons of refuse each year is a problem which has increased with population growth.	
	The tendency for various industries to use single-use packaging techniques for their products has aggravated the refuse disposal problem.	
A. Refuse disposal		
1. Open dumps	Open dumping is the waste disposal method most commonly used today.	
2. Sanitary landfills	Sanitary landfills are dumps where the refuse is added, compacted, and buried beneath a layer of earth.	

dings epts	Laboratory Experiences	Supplementary Information
ge, abandoned tank resi- als, and trash are among the which need isposal.	See A 6.22 for an activity involving the biodegradability of solids.	
of millions efuse each year which has in- population		Most major cities of the world had no systematic refuse collection and disposal programs until well into the 19th century.
for various o use single- g techniques oducts has he refuse blem.		
is the waste thod most ed today.		Open dumps are unsightly, malodorous, and a breeding place for rodents and disease organisms. Because of these disadvantages, it is becoming increasingly difficult for municipalities to find new sites for dumps.
ndfills are the refuse is acted, and ath a layer of		Relatively few land disposal sites are sanitary landfills. An advantage of the sanitary landfill is that the land is reusable again for other purposes.

Topical Outline	Understandings and Concepts	Laboratory Experiences
3. Incineration	Incinerators are used by some of the larger cities to burn their refuse.	For an activity dealing with the problems of incineration, see A 6.23.
		See A 6.24 for finding th scrap value of an aluminu can.
B. Prevention of land pollution	More extensive use of biodegradable, corrodible, and combustible substances for packaging would alleviate the land pollution problem.	
	Many materials now being abandoned can be recycled for further use. The extra cost to manufacture articles from reclaimed materials instead of from new ones is often small.	

ings epts	Laboratory Experiences	Supplementary Information
are used by arger cities refuse.	For an activity dealing with the problems of incineration, see A 6.23.	Incinerators require less room than open dumps but their emissions add to the problems of air pollution, and not all of the materials put into an incinerator can be burned.
	See A 6.24 for finding the scrap value of an aluminum can.	Other methods of refuse disposal include feeding garbage to animals and using *refuse for fill. Ecologically* valuable wetlands near large cities are being destroyed by dumping. Much of San Francisco Bay has been filled in this way. Other large coastal cities load their refuse on barges for disposal at sea.
e use of bio- corrodible, and substances would alle- nd pollution		Desirable packaging alternatives may include the use of cellulose in place of nonbiodegradable wraps, rustable steel in place of aluminum for cans, and paper in place of foils.
s now being be recycled use. The manufacture reclaimed stead of from often small.		Proposals have been made that a "user tax" be put upon manufactured products which could be used to subsidize recycling of their reusable materials. If this was adopted for automobiles alone, it would be more advantageous for the last

Topical Outline	Understandings and Concepts	Laboratory Exper
	The practice of abandoning land after removal of a desirable resource should be avoided.	
	Since many pollutants affect the total environment, prevention of water and air pollution also helps prevent land pollution.	

erstandings d Concepts	Laboratory Experiences	Supplementary Information
		owner of an auto to turn it in for scrap instead of abandoning it.
actice of abandoning fter removal of a ble resource should ided.		Years ago the lumber industry abandoned the "cut-and-slash" philosophy. Conservationists have urged that companies operating open pit and strip mines be required to restore the land they use to its original condition. Communities should be urged to operate landfills instead of dumps for refuse disposal.
many pollutants the total environ- prevention of water r pollution also prevent land pollu-		

AREA 7 - SOME MODERN MATERIALS

The nature of many of the chemicals used in the preparation of polymers makes them unsafe for pupil use. Unless otherwise specified, all polymer preparations shoul be limited to teacher demonstrations carried out under a hood.

Topical Outline	Understandings and Concepts	Laboratory Experie
I. Polymers	A polymer is a substance composed of many repeating units called monomers.	Display some polyme have pupils "classi them. See A 7.01. Use A 7.02 to obtai natural polymer cas from milk.
	The process by which monomers are joined is called polymerization.	To demonstrate monom forming polymers, jo paper clips or safet to make a long chai Add other clips or p make side chains an works.

7 - SOME MODERN MATERIALS

of many of the chemicals used
paration of polymers makes them
pupil use. Unless otherwise
all polymer preparations should
to teacher demonstrations car-
nder a hood.

gs s	Laboratory Experiences	Supplementary Information
bstance repeating mers.	Display some polymers and have pupils "classify" them. See A 7.01.	There are many natural polymers produced by plants and animals.
	Use A 7.02 to obtain the natural polymer casein from milk.	Starch, cellulose, and proteins are natural polymers.
		There are many synthetic polymers.
		Nylon, polyethylene, and Bakelite are examples of synthetic polymers.
ich mono- s called	To demonstrate monomers forming polymers, join paper clips or safety pins to make a long chain.	
	Add other clips or pins to make side chains and networks.	

Topical Outline	Understandings and Concepts	Laboratory Experi
	A plastics material can be described as an artificial material, usually an organic polymer, which at some time in the shaping process is a fluid.	
A. Formation of polymers	Polymers may be formed by condensation or by addition reactions.	Understanding of the merization processes be developed by the stick models.
1. Condensation	A condensation reaction often results from the "splitting out" of a water molecule from monomer units so that the remaining structures bond together.	A 7.03 may be used t illustrate the conde polymerization reacti
	Condensation polymers may undergo more condensations to produce longer chain molecules.	

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Laboratory Experiences

Understanding of the polymerization processes can be developed by the use of stick models.

A 7.03 may be used to illustrate the condensation polymerization reaction.

Supplementary Information

The term plastics has no strictly scientific definition. In most classifications rubber, metal, ceramic, wood, and leather are not considered to be plastics.

If water is "split out," a condensation reaction may also be known as a dehydration synthesis.

A condensation process may be visualized as:

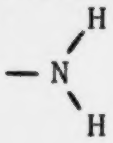
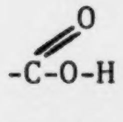
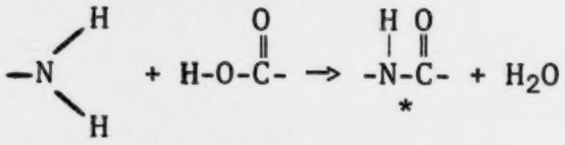
$$\underset{\text{monomer}}{\square\text{-H}} + \underset{\text{monomer}}{\text{HO-}\square} \rightarrow \text{HOH} + \underset{\text{polymer}}{\square\text{-}\square}$$

Condensation polymers do not have the same percentage composition as their monomers.

The monomer of cellulose is glucose, $C_6H_{12}O_6$.
The polymer is
$C_6H_{11}O_5(C_6H_{10}O_5)_nC_6H_{11}O_6$

Each molecule may have from 2,000-9,000 glucose units.

Topical Outline	Understandings and Concepts	Laboratory Experiences
	A catalyst may be used to speed up polymerization reactions. Other chemicals may be added to control the length of the chains.	
2. Addition	An addition polymerization results from the joining of molecules of unsaturated compounds by "opening" double or triple bonds in the carbon chain.	A 7.04 can be used to illustrate the addition polymerization process.
B. Some representative polymers		
1. Polyamides	A polyamide is a polymer obtained from substances containing amine and carboxyl groups.	A 4.09 deals with amide linkages.
	Condensation occurs between the amine and carboxyl groups. The condensation polymer contains an amide linkage.	

rstandings Concepts	Laboratory Experiences	Supplementary Information
t may be used to polymerization . Other chemicals ded to control the the chains.		*Pupils will be expected to recognize a condensation reaction when illustrated by equations using structural formulas.*
on polymerization rom the joining les of unsaturated by "opening" triple bonds in n chain.	A 7.04 can be used to illustrate the addition polymerization process.	The monomer of polyethylene is C_2H_4. The polymer is $(C_2H_4)_n$.
de is a polymer from substances g amine and car- ups.	A 4.09 deals with amide linkages.	Amine group structure is represented by  The carboxylic group has the structure 
ion occurs between and carboxyl The condensation ontains an amide		Condensation resulting in an amide linkage is represented as  $-NH_2 + H\text{-}O\text{-}\overset{O}{\overset{\|}{C}}\text{-} \rightarrow \text{-}\overset{H}{\overset{\mid}{N}}\text{-}\underset{*}{\overset{O}{\overset{\|}{C}}}\text{-} + H_2O$ *An amide linkage is a carbonyl-to-nitrogen bond.

Topical Outline	Understandings and Concepts	Laboratory Experiences
a. Proteins	Proteins are polyamides formed by successive condensation of amino acids. An amino acid is an organic compound containing both an amine group (-NH_2) and an organic acid (carboxyl) group (-COOH). Units of amino acids can function as an amine, as an acid, or as both. By forming amide linkages, amino acids polymerize to form proteins. Proteins are very large molecules.	
b. Nylons	Nylons are polyamide polymers formed by condensation reactions between diamines and dicarboxylic acids.	Teachers can demonstrate the formation of nylon b the use of CH 7.18-b.
2. Phenolic plastics	Phenolic plastics are made by condensation reactions between a phenol and an aldehyde.	A 7.03 involves the cond sation between aldehyde and phenol models.

ngs ts	Laboratory Experiences	Supplementary Information
yamides sive con- no acids.		
an organic ing both -NH_2) and (carboxyl)		
cids can mine, as oth.		
linkages, erize to		
large		
mide poly- ondensation n diamines acids.	Teachers can demonstrate the formation of nylon by the use of CH 7.18-b.	Nylon is a general name for all synthetic fiber-forming polyamides. *Nylon 66 is produced by the reaction between adipic acid and hexamethylenediamine.*
s are made reactions and an	A 7.03 involves the condensation between aldehyde and phenol models.	A phenol is a compound containing one or more benzene ring structures in which hydroxyl groups are united to one or more of the ring carbon atoms.

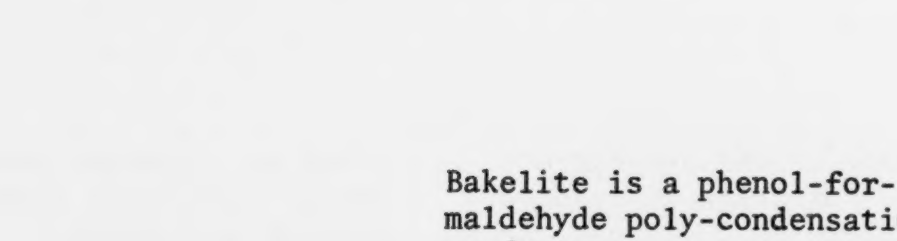
Topical Outline

Understandings and Concepts

Laboratory Experie

Bakelite is a phenol-formaldehyde poly-condensation product.

- Condensation occurs between phenol and formaldehyde monomers:



A teacher demonstrat show the preparation Bakelite type of pol is listed in A 7.05 7.18—a.

Ball-and-stick model be used to illustrat formation of Bakelit

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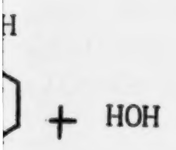


Laboratory Experiences

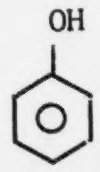
A teacher demonstration to show the preparation of a Bakelite type of polymer is listed in A 7.05 or CH 7.18-a.

Ball-and-stick models can be used to illustrate the formation of Bakelite.

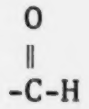
Supplementary Information

The name phenol may be used as a general name for a class of compounds or as a name for the specific compound C_6H_5OH.

The structural formula for the compound phenol is



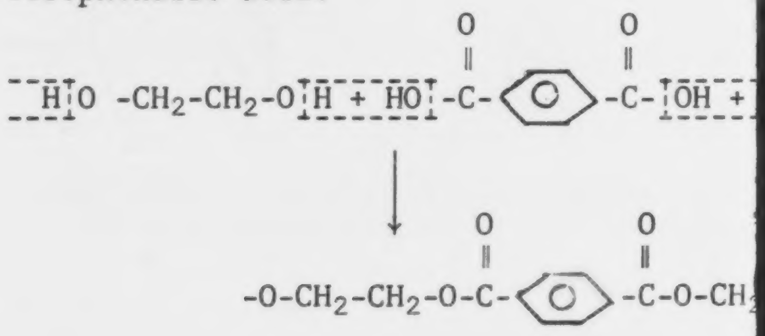
The structural representation of the aldehyde group is



$$\overset{\overset{\displaystyle O}{\|}}{-C-H}$$

Bakelite was the first commercial synthetic polymer.

Topical Outline	Understandings and Concepts	Laboratory
	. Additional condensations lengthen the chain. . Condensation chains can be built on any of the phenol's linkage sites to form a network. . The polymer "sets" into permanent form when this network is built, and the Bakelite plastic is produced.	
3. Polyesters	Polyesters are made by condensation reactions between monomers which are polyhydric alcohols and acids with more than one carboxyl group. Dacron is made by condensation reactions between ethylene glycol and terephthalic acid.	



Dacron

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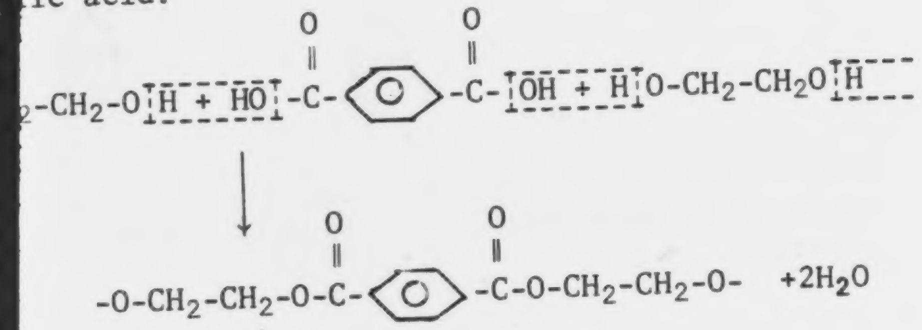
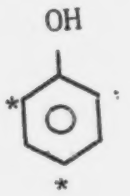
ic acid.



Dacron

Laboratory Experiences

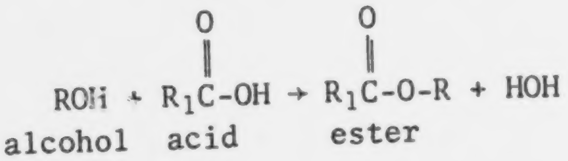
Supplementary Information



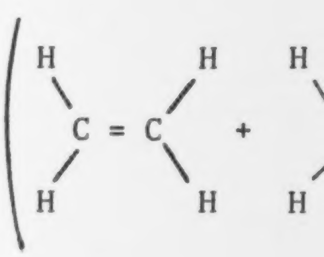
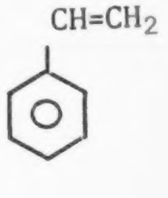
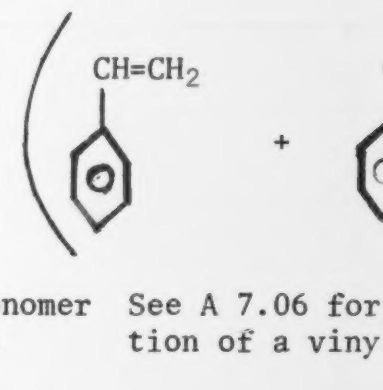
Asterisk (*) indicates most common linkage sites.

Materials with a network structure like Bakelite resist deformation when heated or subjected to pressure.

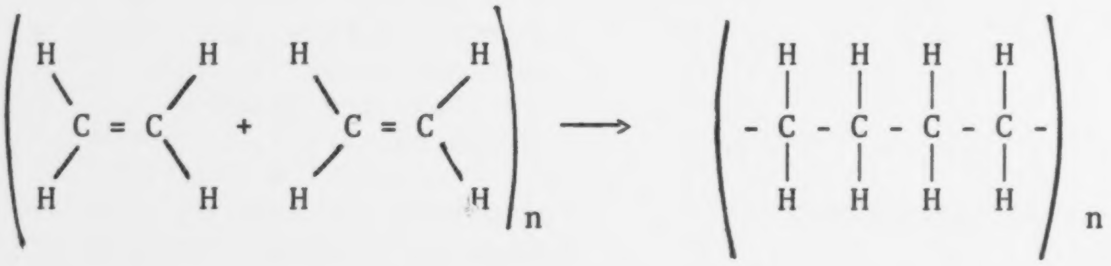
Esters are made by reacting an alcohol and an organic acid.



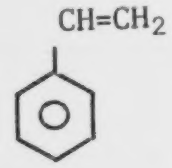
$$ROH + R_1\overset{O}{\overset{\|}{C}}-OH \rightarrow R_1\overset{O}{\overset{\|}{C}}-O-R + HOH$$

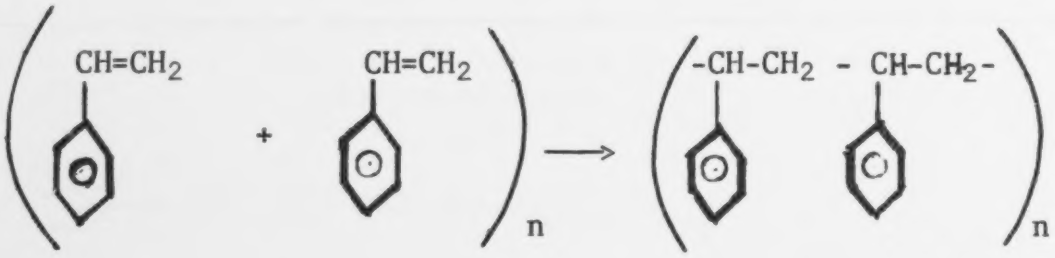
Topical Outline	Understandings and Concepts	Laboratory E
4. Vinyl plastics	Vinyl plastics are formed by addition reaction between monomers containing the C=C structure. The monomer of polyethylene is ethylene, C_2H_4	Pupils can use stick models t formation of t 
	The monomer of polystyrene is styrene 	
	Vinyl chloride is a monomer included in many vinyl plastics.	See A 7.06 for tion of a viny $(CH_2 = CHCl + CH$ Vinyl chloride Vi ch

Understandings and Concepts	Laboratory Experiences	Supplementary Information
Vinyl plastics are formed by addition reaction between monomers containing the C=C structure.	Pupils can use ball-and-stick models to show the formation of the polymers.	The monomers may or may not be identical. However, all must have the C=C structure.
The monomer of polyethylene is ethylene, C_2H_4		Addition polymerization of ethylene can be represented



The monomer of polystyrene is styrene		The addition polymerization of styrene can be represented





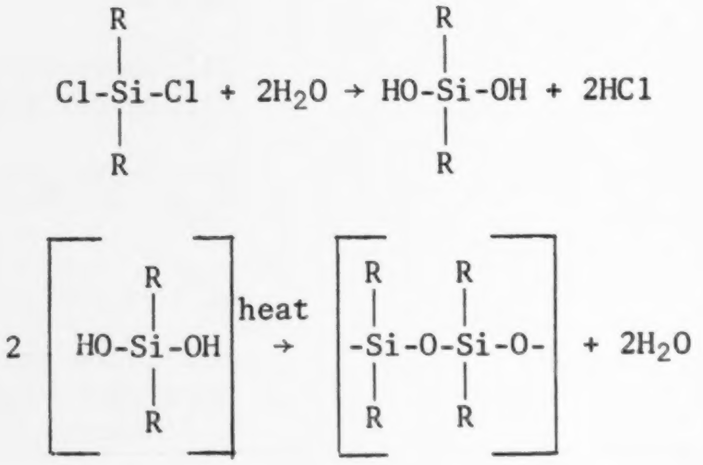
Vinyl chloride is a monomer included in many vinyl plastics.	See A 7.06 for identification of a vinyl chloride.	The monomers for Saran are vinyl chloride and vinylidene chloride.

$$(CH_2 = CHCl + CH_2 = CCl_2)_n \longrightarrow [-CH_2CHCl-CH_2CCl_2-]_n$$

Vinyl chloride   Vinylidene chloride   Saran

Topical Outline	Understandings and Concepts	Laboratory Experie
5. Silicones	Silicones are polymers having a chain structure of -Si-O-Si-O-.	Models can be used t the silicone chain. "Bouncing" or "silly shows interesting be
a. Synthesis	Silicones are formed by hydrolysis of organo-silicon chlorides, followed by a condensation reaction between the silicon monomers.	

rstandings Concepts	Laboratory Experiences	Supplementary Information
are polymers chain structure Si-O-.	Models can be used to show the silicone chain. "Bouncing" or "silly" putty shows interesting behavior.	Silicon can form four covalent bonds. Although the silicon atoms can covalently bond to other silicon atoms, long silicon chains are not possible. However, long chains containing -Si-O-Si-O- linkages are stable.
are formed by s of organo- hlorides, followed ensation reaction he silicon mono-		



$$\mathrm{Cl{-}\overset{R}{\underset{R}{Si}}{-}Cl + 2H_2O \rightarrow HO{-}\overset{R}{\underset{R}{Si}}{-}OH + 2HCl}$$

$$2\left[\mathrm{HO{-}\overset{R}{\underset{R}{Si}}{-}OH}\right] \xrightarrow{\text{heat}} \left[\mathrm{{-}\overset{R}{\underset{R}{Si}}{-}O{-}\overset{R}{\underset{R}{Si}}{-}O{-}}\right] + 2\mathrm{H_2O}$$

Successive condensations lengthen the chain.

Networks can be obtained if the synthesis starts with an organosilicon trichloride.

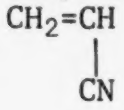
Topical Outline	Understandings and Concepts	Laboratory Ex
b. Properties	The properties of the silicones depend upon the structure of the chain and the nature of the groups of atoms attached to the chain.	
	Silicones tend to be relatively inert and noncombustible.	
	Silicones are excellent electrical insulators.	
	Silicones are water repellent.	
	Silicones have properties which are stable over a wide range of temperatures.	Compare the eff ing water on pa and on a silico wax.
C. Some types of polymers	A particular polymer may have one or more of the characteristics described below.	
1. Elastomers	Elastomers are polymers showing some degree of elasticity.	Show the elasti (within limits) of synthetic ru Measure the len during, and aft ing it.

andings ncepts	Laboratory Experiences	Supplementary Information
es of the sil- d upon the the chain and f the groups ached to the		Short chain silicones are oils and greases rather than plastics.
nd to be rela- and noncom-		Silicone resins in paints form lasting finishes.
e excellent nsulators.		Silicone rubbers are not affected by heat.
e water repel-		The viscosity of silicone oils does not significantly change at low or high temperatures.
ve properties able over a f temperatures.	Compare the effect of boiling water on paraffin wax and on a silicone stopcock wax.	Silicones retain their plasticity regardless of pressure or heat.
polymer may more of the ics described		
re polymers degree of	Show the elastic property (within limits) of a piece of synthetic rubber. Measure the length before, during, and after stretching it.	Polyisoprene, neoprene, and butadiene-styrene are examples of elastomers.

Topical Outline	Understandings and Concepts	Laboratory Experie
	Elastomers have long "folded" molecules that act like a "molecular spring." Upon being stretched, the molecules stretch out. When the stretching force is released, the molecules resume their folded position.	Stretching a rubber requires energy. Wh band returns to the inal shape, energy i released. This ener change can be detect as heat by holding a band across the lips band is stretched an returned to its orig shape.
	Elastomers may be addition or condensation polymers which may contain one or two kinds of monomers.	Teachers can demonst the formation of a s thetic rubber by the of CH 7.18-c.
	Polymers formed from two or more kinds of monomers are called copolymers.	
	Some elastomers such as neoprene are resistant to organic solvents, chemicals, and air oxidation.	Compare the effect o nail polish remover, HCl on natural rubbe neoprene.
2. Fibers	Fibers are polymers composed of long molecules which can align themselves close together to form strands.	Natural and syntheti can be identified by scopic inspection. threads of a synthet tend to be smooth an cylindrical.

derstandings nd Concepts	Laboratory Experiences	Supplementary Information
ers have long " molecules that e a "molecular " Upon being ed, the molecules out. When the ing force is d, the molecules their folded posi-	Stretching a rubber band requires energy. When the band returns to the original shape, energy is released. This energy change can be detected as heat by holding a rubber band across the lips as the band is stretched and returned to its original shape.	Elasticity is the ability of a substance to return to its original shape after being deformed.
ers may be addition ensation polymers ay contain one or ds of monomers.	Teachers can demonstrate the formation of a synthetic rubber by the use of CH 7.18-c.	*Neoprene is synthesized by changing acetylene to vinylacetylene to a chloroprene monomer. The chloroprene monomers polymerize and are vulcanized into neoprene.*
s formed from two kinds of monomers led copolymers.		GRS rubber is a copolymer of butadiene and styrene.
astomers such as e are resistant to solvents, chem- and air oxidation.	Compare the effect of NaOH, nail polish remover, and HCl on natural rubber and neoprene.	
are polymers com- f long molecules an align themselves ogether to form .	Natural and synthetic fibers can be identified by microscopic inspection. The threads of a synthetic fiber tend to be smooth and cylindrical.	Linen, cotton, silk, and wool are natural fibers. Dacron and Orlon are synthetic fibers.

Topical Outline	Understandings and Concepts	Laboratory Exp
	When some synthetic fiber chains are rearranged by stretching them so they are parallel and closely packed, the fiber becomes stronger.	
	Synthetic fibers have some properties like those of natural fibers. They may also have dissimilar properties.	Use A 7.07 for a of the propertie fibers. Properties such strength and res abrasion can be also.
3. Thermoplastic polymers	Thermoplastics soften on heating and harden on cooling. Thermoplastics may be repeatedly softened and hardened.	Changing the sha thermoplastic ma illustrated in A
	The long chain molecules are held in place by "mutual entanglement" or by crystallinity when the plastic is cold.	The disappearanc tallinity occurs temperature when lucent plastic b transparent. A demonstration is some paraffin wa a candle.
	When a thermoplastic is heated, the long chain molecules can slide over one another to form a different shaped solid.	

derstandings nd Concepts	Laboratory Experiences	Supplementary Information
ne synthetic fiber are rearranged by ing them so they allel and closely the fiber becomes r.		Polymers forming high tensile strength fibers can be used for fabrics: Orlon, Dacron, nylon, Vinyon, and viscose rayon yarns. Orlon is made by an addition reaction between acrylonitrile units,  $CH_2{=}\underset{\overset{\vert}{CN}}{CH}$
ic fibers have some ies like those of fibers. They may ve dissimilar prop-	Use A 7.07 for a comparison of the properties of fibers. Properties such as wet strength and resistance to abrasion can be tested also.	
lastics soften on and harden on . Thermoplastics repeatedly softened dened.	Changing the shape of a thermoplastic material is illustrated in A 7.08.	Lucite, polystyrene, and saran are examples of thermoplastic substances.
g chain molecules d in place by entanglement" or tallinity when the is cold. thermoplastic is the long chain es can slide over ther to form a nt shaped solid.	The disappearance of crystallinity occurs at a temperature when a translucent plastic becomes transparent. A simple demonstration is to melt some paraffin wax or burn a candle.	*Lucite is the acrylic resin, methyl methacrylate.*

Topical Outline	Understandings and Concepts	Laboratory Expe
4. Thermosetting and cold-setting plastics	Thermosetting plastics soften upon being heated, but undergo changes in structure which set the material in a permanent form.	
	When plastic "sets," the chains cross-link to form a network. The chains no longer can be moved across each other.	
	By undergoing a chemical change with a catalyst, some plastics can set at room temperature. They are called cold-setting plastics.	A 7.09 deals with setting plastic.
	Like thermosetting plastics, cold-setting plastics cannot be resoftened once they have been shaped and hardened.	
	Thermosetting and cold-setting plastics are resistant to high temperatures.	For an activity that used to test for the plastic and thermose properties, see A 7. Pupils can classify of plastics by A 7.1

Understandings and Concepts	Laboratory Experiences	Supplementary Information
Thermosetting plastics soften upon being heated, but undergo changes in structure which set the material in a permanent form.		The temperatures and pressures needed for molding articles from thermosetting plastics cannot be safely obtained in the high school laboratory.
When plastic "sets," the chains cross-link to form a network. The chains no longer can be moved across each other.		An example of a thermosetting plastic is Bakelite.
By undergoing a chemical change with a catalyst, some plastics can set at room temperature. They are called cold-setting plastics.	A 7.09 deals with a cold-setting plastic.	
Like thermosetting plastics, cold-setting plastics cannot be resoftened once they have been shaped and hardened.		
Thermosetting and cold-setting plastics are resistant to high temperatures.	For an activity that can be used to test for thermoplastic and thermosetting properties, see A 7.10. Pupils can classify kinds of plastics by A 7.11.	

Topical Outline	Understandings and Concepts	Laboratory Experie
II. Industrial Metals	An industrial metal generally contains other elements which may be metallic or nonmetallic.	
	The additional elements in an industrial metal may be either the "natural" impurities left after metallurgical treatment of their ores, or "artificial" impurities deliberately injected by the metallurgist.	
	Adding other elements to a metal is called alloying.	
	An industrial metal containing significant amounts of other elements is called an alloy.	
A. "Natural" impurities	Most metals are found in the combined form as oxides, sulfides, or carbonates, along with other rock-like materials.	
1. Concentration of ore	Concentration of the ore involves removal of unwanted nonmetallic minerals in order to make the metallurgy of a mineral more economical.	CH 8.26 a, b, c(1), d deal with concent processes.

andings ncepts	Laboratory Experiences	Supplementary Information
l metal gener- s other ele- may be metallic ic.		Pure substances are seldom encountered in modern metallic materials.
al elements in l metal may be 'natural" impur- fter metal- atment of their tificial" eliberately the metallur-		The carbon, sulfur, phosphorus, and oxygen left in cast iron are examples of "natural" impurities.
elements to a lled alloying.		
al metal con- nificant amounts ements is called		
are found in d form as fides, or car- ong with other aterials.		
on of the ore moval of nmetallic min- der to make the of a mineral ical.	CH 8.26 a, b, c(1), c(2), d deal with concentration processes.	

Topical Outline	Understandings and Concepts	Laboratory
	Substances may be separated if they differ in their density, or in their ability to be attracted by a magnet, to be wet by water, or to "attract" air bubbles.	
	Substances may be separated by changing their ability to attract water by means of xanthates.	Concentrating tation can be by CH 8.27.
	Some metallic compounds become magnetic by partial reduction of the compound.	See CH 8.28.
2. Reduction	Most metallic oxides are reduced by carbon and carbon monoxide.	CH 8.19, CH 8. hood), and CH fume hood) can illustrate the metallurgical
	Sulfides and carbonates must be converted to oxides before reduction.	
	Some nonmetallic impurities that may be left after reduction are sulfur, phosphorus, carbon, oxygen, and silicon.	
	Metallic impurities left in the metal generally include metals having similar properties.	

andings ncepts	Laboratory Experiences	Supplementary Information
ay be separated er in their in their abil- tracted by a e wet by water, ct" air		
ay be separated their ability ater by means .	Concentrating ores by flotation can be illustrated by CH 8.27.	
c compounds tic by partial the compound.	See CH 8.28.	Hematite heated with charcoal can produce a magnetic oxide which can be separated easily from nonmagnetic materials.
c oxides are arbon and car- . carbonates erted to oxides tion. llic impurities left after e sulfur, phos- on, oxygen,	CH 8.19, CH 8.21-a (use fume hood), and CH 8.22 (use fume hood) can be used to illustrate the general metallurgical processes.	*Pupils will be expected to know the following general reactions and how to use them to obtain Fe, Zn, Pb, and Sn.* *Metallic oxide* + $C \rightarrow CO$ + *metal* *Metallic oxide* + $CO \rightarrow CO_2$ + *metal* *Metallic sulfide* + $O \rightarrow SO_2$ + *metallic oxide* *Metallic carbonate* $\rightarrow CO_2$ + *metallic oxide.*
urities left generally ls having sim- ies.		*Pupils are not responsible for knowing the construction of furnaces and converters.*

Topical Outline	Understandings and Concepts	Laboratory Experie
B. "Artificial" impurities - alloying	Artificial impurities are generally added by melting all of the metals together and cooling the melt to produce the alloy.	Make Wood's metal or by using CH 8.42c (1 (2).
C. Properties and uses of alloys	Alloying an element with a metal produces a substance with properties unlike those of the components.	
	An alloy tends to be harder than any of its components. . Pure silver is made harder by alloying with copper. The silver-copper alloy is used to make sterling silver for tableware and jewelry.	CH 8.42-b can be use illustrate how atoms different sizes may the hardness of the
	An alloy tends to have a melting point that is lower than those of the components. . Wood's metal, composed of tin, cadmium, and lead, melts in hot water, but none of the components do.	

nderstandings and Concepts	Laboratory Experiences	Supplementary Information
		The nonmetallic impurities left in cast iron cause brittleness.
cial impurities are lly added by melting the metals together ling the melt to the alloy.	Make Wood's metal or solder by using CH 8.42c (1) or (2).	Some molten metals are immiscible. Alloys of these metals are made from mixtures of very fine powders of the metals. The mixtures are heated under pressure.
g an element with a roduces a substance operties unlike f the components.		Carbon increases brittleness.
y tends to be harder y of its components. silver is made r by alloying with r. The silver- r alloy is used to sterling silver for ware and jewelry.	CH 8.42-b can be used to illustrate how atoms of different sizes may affect the hardness of the alloy.	Aluminum, manganese, magnesium, and chromium increase resistance to corrosion. Copper increases hardness. Bismuth decreases the melting point.
y tends to have a point that is lower ose of the compo-		*Pupils will be held responsible for knowing that varying the percentage composition of an alloy may change its properties. However, they are not expected to memorize the percentage composition of alloys.*
s metal, composed of cadmium, and lead, in hot water, but of the components		

Topical Outline	Understandings and Concepts	Laboratory Experiences
	An alloy tends to be a poorer conductor of electricity (has higher electrical resistance) than any of its components. . A nickel-chromium alloy called nichrome has so much resistance to electrical current that it is used for the heating elements in electrical toasters.	
	An alloy tends to be less active than any of its components. . Stainless steel is relatively slow to react with most chemicals. Chromium is one of the constituents of stainless steel.	
III. Radioisotopes		
A. Nature of radioactivity		When working with radioisotopes, particularly those in unsealed containers, it is essential that the rules for handl these materials be follo at all times. A list of these precautions is giv in CH 6.02.

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nds to be a
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s higher elec-
stance) than
components.
chromium alloy
chrome has so
stance to elec-
rrent that it
or the heating
in electrical

nds to be less
any of its com-

steel is rela-
ow to react with
icals. Chromium
the constitu-
tainless steel.

Laboratory Experiences

When working with radioisotopes, particularly those in unsealed containers, it is essential that the rules for handling these materials be followed at all times. A list of these precautions is given in CH 6.02.

Supplementary Information

Pupils will have encountered some of the concepts listed at the left in Science 7,8, 9, Block L (pp. 2-61).

The Atomic Energy Commission's series of booklets entitled "Understanding the Atom" is a very complete set covering all topics on radioisotopes included in this unit. Complete sets of the series are available free to school librarians

Topical Outline	Understandings and Concepts	Laboratory Exper
	A radioisotope is any isotope which undergoes radioactive decay, with the emission of a characteristic radiation.	Hide a source of ra activity. Have a pupils locate it by a detecting instru
1. Stability of nuclei	Nuclei of radioisotopes achieve stability through radioactive decay. Some radioisotopes decay at a *faster rate than others.* Elements can be made radioactive by bombarding them with high energy particles, such as protons (${}^1_1H$), neutrons (${}^1_0n$), and alpha particles (${}^4_2He$). These elements can then emit charged particles from their nuclei and become atoms of a different element if the number of protons in the nucleus changes. ${}^4_9Be + {}^1_1H \rightarrow {}^3_6Li + {}^2_4He$	
2. Nuclear energy	When a nuclear particle is emitted, a small amount of mass is converted into kinetic energy of the particle.	For a discussion o equivalence of matt energy, see CH 6.14.

Understandings and Concepts	Laboratory Experiences	Supplementary Information
A radioisotope is any isotope which undergoes radioactive decay, with the emission of a characteristic radiation.	Hide a source of radioactivity. Have a team of pupils locate it by use of a detecting instrument.	*and to teachers, who can make them available for reference or for use by groups. Requests made on school or library letterheads, indicating the proposed use, should be sent to USAEC, P.O. Box 62, Oak Ridge, Tennessee 37830.*
Nuclei of radioisotopes achieve stability through radioactive decay. Some radioisotopes decay at a faster rate than others.		One cannot predict that a particular nucleus of a radioisotope will decay at a given time.
Elements can be made radioactive by bombarding them with high energy particles, such as protons (^1_1H), neutrons (^1_0n), and alpha particles (^4_2He). These elements can then emit charged particles from their nuclei and become atoms of a different element if the number of protons in the nucleus changes.		*Pupils will be expected to recognize transmutations when illustrated by equations.*
$^4_9Be + ^1_1H \rightarrow ^3_6Li + ^2_4He$		
When a nuclear particle is emitted, a small amount of mass is converted into kinetic energy of the particle.	For a discussion on the equivalence of matter and energy, see CH 6.14.	The mass-loss is converted into energy according to Einstein's statement of equivalence of mass and energy, $E=mc^2$.

Topical Outline	Understandings and Concepts	Laboratory Experi
	The kinetic energy possessed by radioactive decay particles is transformed into thermal or radiant energy, which may be used to produce electrical energy through a number of energy conversion techniques.	
	The production of energy by nuclear means may be accomplished by fission and fusion reactors.	
a. Fission reactors	In a nuclear reactor, a controlled fission process occurs when neutrons moving at the proper speed penetrate the nucleus of a fissionable atom, causing it to cleave apart and release other neutrons to carry on the fission process with another fissionable atom. The radioisotopes U^{235} and Pu^{239} are fissionable and emit enough neutrons to sustain or increase the rate at which fission takes place. Large amounts of heat are released by the fission process; this heat can be used to make steam for the production of electric power.	

ndings ncepts	Laboratory Experiences	Supplementary Information
		Pupils will not be held responsible for calculating the energy released during a nuclear transformation.
energy possessed ve decay parti- sformed into adiant energy, used to produce nergy through a ergy conversion		All processes for making potable water from saline water consume energy. It has been found that nuclear energy is economical for large-size desalting plants.
on of energy by s may be by fission and ors.		
reactor, a ission process neutrons moving r speed pene- cleus of a atom, causing it art and release ns to carry on process with ionable atom. topes U^{235} and ssionable and neutrons to ncrease the n fission Large amounts released by the ess; this heat to make steam uction of er.		*Pupils are not responsible for knowing the construction of nuclear reactors.* The nuclear reactors used by electric companies require large amounts of water to cool the reactor. This heated water when released into a stream or lake may cause a thermal pollution problem.

Topical Outline	Understandings and Concepts	Laboratory Experiences
	The fission products from nuclear reactors are highly radioactive and cannot be discarded as ordinary wastes. They must be stored for a long time or disposed of in special ways.	
b. Fusion reactors	In a fusion reaction, nuclei of lighter elements combine to form a nucleus of a heavier element. The mass of the heavier nucleus is less than the sum of the masses of the lighter nuclei; the difference in mass is converted into energy.	
	The radioactive waste from a fusion process is considerably less than that from the fission process.	
3. Major types of nuclear radiation	Nuclear particles or electromagnetic radiations of major importance emitted by radioisotopes are alpha particles, beta particles, gamma rays, and neutrons.	For use of a Geiger counte see A 7.12 and A 7.13.
a. Alpha particles	Alpha radiation consists of helium nuclei having a mass of approximately 4 a.m.u. and a charge of plus 2.	
b. Beta particles	Beta radiation consists of electrons emitted from the nucleus. Their mass is 1/1836 of a proton, and they carry a single negative charge.	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
ssion products from r reactors are highly ctive and cannot be ded as ordinary wastes. ust be stored for a ime or disposed of in l ways.		This problem is increasing as more nuclear reactors are put into use by the electrical industry.
usion reaction, nuclei hter elements combine m a nucleus of a r element. The mass heavier nucleus is han the sum of the of the lighter nuclei; fference in mass is ted into energy.		Fusion reactions are responsible for the emission of energy from the stars. Work is being done to develop fusion reactors which can maintain the fusion reaction long enough for the heat from the reaction to be used.
dioactive waste from on process is consid- less than that from ssion process.		
r particles or elec- netic radiations of importance emitted by sotopes are alpha les, beta particles, rays, and neutrons.	For use of a Geiger counter, see A 7.12 and A 7.13.	
radiation consists of nuclei having a mass roximately 4 a.m.u. charge of plus 2.		Alpha particles have ranges in air of only a few centimeters and can be stopped by a single sheet of paper.
adiation consists of ons emitted from the s. Their mass is of a proton, and they a single negative .		Beta particles are more penetrating than alphas, but can be stopped by thin sheets of aluminum.

Topical Outline	Understandings and Concepts	Laboratory Experi
c. Gamma rays	Gamma radiations are very high frequency electromagnetic waves. These waves have shorter wave lengths than X rays. Gamma radiations have no charge or mass.	
d. Neutrons	Neutron radiation is the emission of neutrons from the nucleus of a radioisotope. This happens in fission and some fusion reactions. The neutron has a mass of approximately 1 a.m.u. and no charge.	
B. Some properties and uses of radioisotopes	Some properties of radioisotopes have made them useful in many areas, such as medical diagnosis, biochemistry, geology, and therapy.	
1. Uses based on chemical reactivity	Radioisotopes are chemically similar to the nonradioactive isotopes of the same element. Many radioisotopes are used as tracers. They are added to a system to enable the experimenter to follow the course of a reaction without seriously altering the conditions.	Preparing radioacti for absorption by p is described in A 7

Understandings and Concepts	Laboratory Experiences	Supplementary Information
mma radiations are very gh frequency electro- gnetic waves. These ves have shorter wave ngths than X rays. Gamma diations have no charge mass.		Gamma radiations are highly penetrating and present one of the greatest potential hazards to humans.
utron radiation is the ission of neutrons from e nucleus of a radio- otope. This happens in ssion and some fusion actions. The neutron s a mass of approximately a.m.u. and no charge.		Both gamma radiation and neutrons are very penetrating. Strictly speaking, it is not possible to absorb gamma radiation completely. However, a sheet of lead 5 centimeters thick will stop more than 99 percent of a beam of gamma radiation. Neutrons can be stopped, but they have been known to penetrate 20 centimeters of lead.
me properties of radio- otopes have made them use- l in many areas, such as dical diagnosis, biochem- try, geology, and therapy.		
dioisotopes are chemical- similar to the non- dioactive isotopes of the me element.	Preparing radioactive CO_2 for absorption by plants is described in A 7.14.	The use of C^{14} as a tracer has given us a better understanding of the mechanisms of many organic reactions.
ny radioisotopes are used tracers. They are added a system to enable the perimenter to follow the urse of a reaction with- t seriously altering the nditions.		Some of the complex biochemical pathways in photosynthesis have been traced by using C^{14}.

Topical Outline	Understandings and Concepts	Laboratory Experience
2. Uses based on radioactivity	Radioisotopic tracers are detected by the radiation they emit.	For determining the minimum activity of a radioisotope required f detection, see A 7.15.
	Radioisotopes are used in medical diagnosis.	For activities related medical and industrial uses of tracers, see A 7 and A 7.17.

standings Concepts	Laboratory Experiences	Supplementary Information
pic tracers are y the radia- emit.	For determining the minimum activity of a radioisotope required for detection, see A 7.15.	
pes are used in agnosis.	For activities related to medical and industrial uses of tracers, see A 7.16 and A 7.17.	To minimize radiation damage when tracing, a physician or radiologist will select an isotope with a short half-life and which will be quickly eliminated from the body. As a further precaution, the smallest possible amount of the isotope that can be accurately detected will be used. Diagnostic injections of radioisotopes destroy less than .01 percent of the viable cells. Tc^{99} is being used successfully by neurosurgeons to pinpoint brain tumors. Tumors in the brain are known to concentrate technetium much more than do healthy brain cells. Formerly, P^{32} was used for this purpose. I^{131} is taken up by the thyroid gland. The rate of uptake can be used to diagnose hyper- and hypothyroidism.

Topical Outline	Understandings and Concepts	Laborato
	Radioisotopes are used in therapy.	
	Ionizing radiations damage or destroy cells in general, but the cells most vulnerable are those most frequently undergoing division.	
	Foods exposed to low levels of radiation can be kept much longer before spoiling. The radiations kill bacteria, yeasts, molds, and insect eggs.	
	Some radiation is absorbed as it passes through matter. By placing a source of radiation on one side of a moving object and a detector on the other side, physical dimensions or other properties of the object can be monitored.	For an act gauging, se

Understandings and Concepts	Laboratory Experiences	Supplementary Information
ioisotopes are used in rapy.		
izing radiations damage destroy cells in eral, but the cells t vulnerable are those t frequently undergoing ision.		A cancer, by definition, consists of rapidly dividing cells. Therapeutic injections of radioisotopes contain about 1,000 times more activity than diagnostic injections. Radium, cobalt-60, and iodine-131 are used in cancer therapy.
ds exposed to low levels radiation can be kept h longer before spoil- g. The radiations kill teria, yeasts, molds, and ect eggs.		Some meats have been stored after irradiation for considerable lengths of time without refrigeration. The use of irradiation has been approved for sprout inhibition of white potatoes and disinfestation of wheat and flour from insects.
e radiation is absorbed it passes through tter. By placing a rce of radiation on one de of a moving object and detector on the other de, physical dimensions other properties of the ect can be monitored.	For an activity involving gauging, see A 7.18.	Radioisotope thickness gauges are being used to measure the thickness during manufacture of such products as paper, metal sheets, textiles, tire fabrics, and floor coverings. A gauge is also in use in the beverage industry which causes unfilled and partially filled cans and bottles to be rejected from the assembly line.

Topical Outline	Understandings and Concepts	Laboratory Experience
3. Uses based on rate of decay and half-life	The rate of radioactive decay (the rate of emission of nuclear radiation) is usually expressed by means of the half-life of the particular isotope involved. The time required for one-half of a given number of radioactive atoms to undergo decay is the half-life for that radioisotope. After 1, 2, 3, or 4 half-lives, the activity of the radioisotope will fall, respectively, to 1/2, 1/4, 1/8, or 1/16 of its initial value.	For half-life measureme see A 7.19 and CH 6.13a
	The half-life of a radioactive element is considered a constant. The rate of decay of radioisotopes is not changed by heat, pressure, state of chemical combination of the element, or time.	See CH 6.10 for the lac effect of chemical chan on radioactivity.

dings epts	Laboratory Experiences	Supplementary Information
		Radioisotopes are also used in polymerization, polymer modification, catalysis, fiber modification, growth acceleration and inhibition, insect control, sterilization of pharmaceuticals and medical equipment, friction and wear determinations, and nondestructive testing.
dioactive de- of emission iation) is sed by means fe of the tope involved. red for one- n number of oms to undergo alf-life for ope. After 1, -lives, the e radioisotope pectively, to or 1/16 of its	For half-life measurements, see A 7.19 and CH 6.13a.	
of a radio- is con- tant. The of radio- changed ure, state mbination , or time.	See CH 6.10 for the lack of effect of chemical change on radioactivity.	*Pupils are not expected to memorize the half-life value of any radioisotope.*

Topical Outline	Understandings and Concepts	Laboratory Ex
	Radioisotopes give a fairly consistent method of dating some geologic events.	
	U^{238} has a half-life of 4.5 billion years. The stable product is Pb^{206}.	
	Radiocarbon, C^{14}, found in CO_2 in the atmosphere, disintegrates spontaneously to N^{14}. Its half-life is about 5,580 years.	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
oisotopes give a ly consistent method ating some geologic ts.		
has a half-life of billion years. The le product is Pb^{206}.		Many minerals contain measurable amounts of uranium. By finding the ratio of Pb^{206} to the U^{238} still remaining, the age of the mineral can be computed.
		In addition to the decay of U^{238} to Pb^{206}, similar radioactive pairs such as K^{40}/Ar^{40} and Sr^{87}/Rb^{87} have been used for dating.
ocarbon, C^{14}, found in in the atmosphere, dis- egrates spontaneously to . Its half-life is about 30 years.		The fact that the ratio of isotopes in the carbon from living matter is the same as that of the carbon in the air means that a measurement of the C^{14} content of an old piece of wood or shell may give a measure of the time elapsed since the organism died and ceased to acquire new carbon from the air or water.
		Because the half-life of C^{14} is very much shorter than that of uranium, it is valuable in dating material of relatively recent origin (not more than about 40,000 years old).

Topical Outline	Understandings and Concepts	Laboratory Experiences
C. Detection of nuclear radiation	Most methods for detecting radiation depend upon the detection of ionization caused by radiation.	
1. Film	Photographic film is sensitive to radiation from radioisotopes.	For making radioautographs using coleus leaves and X-ray film, see CH 6.11.
2. Electroscope	A charged electroscope is discharged faster when the air around it is ionized by radiation.	Place a source of radiation near the knob of a charged electroscope and note the rate at which the electroscope discharges. Use another charged electroscope as a control.
3. Geiger counter	Geiger counters are best for counting beta particles. Alpha particles are stopped by the window unless it is very thin. Only a small percent of the gamma radiation entering the tube activates the counter.	For information pertaining to the Geiger counter, see CH 6.05.
4. Scintillation counter	Scintillation counters are more efficient for counting gamma radiation and can also measure much higher levels of radiation than the Geiger counter.	

rstandings Concepts	Laboratory Experiences	Supplementary Information
ods for detecting depend upon the of ionization radiation.		*Pupils are not responsible for knowing the construction of radiation-counting instruments.*
hic film is to radiation oisotopes.	For making radioautographs using coleus leaves and X-ray film, see CH 6.11.	X-ray film is more suitable than ordinary photographic film for making radioautographs.
electroscope is ed faster when the nd it is ionized ion.	Place a source of radiation near the knob of a charged electroscope and note the rate at which the electroscope discharges. Use another charged electroscope as a control.	
ounters are best ing beta parti- lpha particles are by the window is very thin. all percent of radiation enter- ube activates er.	For information pertaining to the Geiger counter, see CH 6.05.	Radiation entering through the window of a Geiger counting tube causes ionization of gas molecules in the tube. This results in a pulse of current which registers on a meter or is indicated in various other ways.
ation counters efficient for gamma radiation lso measure much vels of radiation Geiger counter.		Radiation striking the crystal detector of a scintillation counter causes a small flash of light which is amplified by a photomultiplier tube, producing a current which registers on a meter.

Topical Outline	Understandings and Concepts	Laboratory Ex
D. Radiation and human safety	Radiations emitted by radioisotopes can cause damage to living cells by the ionization they produce.	A list of rules laboratory proc be followed whe with radioisotop given in CH 6.0
	The amount of ionization produced depends upon the radiation rate, exposure time, and the radiation source.	A 7.20 deals wit effects of radi seeds.
	Atoms of nonradioactive isotopes cannot be made radioactive by exposure to the radiation emitted by the natural decay of radioisotopes.	See A 7.21 for an regarding radioac out in rain and s

ndings cepts	Laboratory Experiences	Supplementary Information
itted by can cause ing cells by n they pro-	A list of rules for laboratory procedures to be followed when working with radioisotopes is given in CH 6.02.	It is extremely important that rules of laboratory procedure be established and enforced when working with unsealed radioisotopes. No activity should ever be considered in which the radioisotopes are ingested by humans.
ionization nds upon the e, exposure radiation	A 7.20 deals with the effects of radiation on seeds.	Units of radiation measurement have been established which are used in maintaining health and safety standards. The roentgen applies only to X rays and gamma rays. One roentgen of radiation produces about 1.8×10^{12} ion pairs per gram of tissue. The Roentgen Equivalent Man, known as the REM, is that quantity of any kind of radiation which produces the same biological damage as 1 roentgen of X rays. A whole body exposure of 500 REM is usually lethal.
radioactive not be made by exposure tion emitted al decay of s.	See A 7.21 for an activity regarding radioactive fallout in rain and snow.	Different kinds of radiation differ in their Relative Biological Effectiveness (RBE). An alpha particle causes 20 times as much damage to tissue as

Topical Outline	Understandings and Concepts	Laboratory Experienc
	Atoms are made radioactive only when they have been exposed to high energy particles, such as those produced by accelerators, nuclear reactors, and thermonuclear explosions.	Using a radioisotope t determine the efficien a cleanser is describe in A 7.22.

ings pts	Laboratory Experiences	Supplementary Information
radioactive have been energy as those elerators, s, and xplosions.	Using a radioisotope to determine the efficiency of a cleanser is described in A 7.22.	a gamma radiation. Its RBE is 20. Protons cause 10 times as much damage to tissue as gamma radiation. Their RBE is 10. Beta particles have an RBE of 1.

AREA 8 - CHEMICAL ANALYSIS

Since this area lends itself so wel
laboratory work, there may be more
ities listed than can be completed
allotted time. Teachers should cho
the activities which best meet the
situation.

Topical Outline	Understandings and Concepts	Laboratory Ex
I. Qualitative Analysis	Qualitative analysis is the identification of the substances present in a sample of matter.	A major part o ratory work sh of the identifi ions or substan tained in unkn
	Qualitative analysis depends upon similarities and dissimilarities in the properties of ions, atoms, or molecules.	
A. Precipitation	An insoluble substance formed in reacting solutions is called a precipitate.	Identification known precipita volved in A 8.0
	Some ions are identified by the precipitates they can form.	A 8.02 deals wi aration of two ted ions.
		Identification o ions by precipit given in A 8.03.

AREA 8 - CHEMICAL ANALYSIS

Since this area lends itself so well to laboratory work, there may be more activities listed than can be completed in the allotted time. Teachers should choose the activities which best meet the local situation.

derstandings nd Concepts	Laboratory Experiences	Supplementary Information
tive analysis is ntification of the ces present in a of matter.	A major part of the laboratory work should consist of the identification of ions or substances contained in unknown samples.	Qualitative analysis may also identify structural details of a sample of matter.
tive analysis upon similarities similarities in perties of ions, or molecules.		*Pupils will be held responsible for identification of ions on the basis of properties such as solubility and color which can be determined from reference charts.*
luble substance in reacting solu- s called a precip-	Identification of an unknown precipitate is involved in A 8.01.	A slightly soluble substance can be made to precipitate by concentrating and cooling its solution.
ns are identified precipitates they m.	A 8.02 deals with the separation of two precipitated ions.	
	Identification of halide ions by precipitation is given in A 8.03.	

Topical Outline	Understandings and Concepts	Laboratory Experiences
	Mixtures of some ions can be separated by successive precipitation.	Use the separation of Group I (Ag^+, Hg^{++}, and Pb^{++}) to show successive precipitations. Directions can be found in mos analytic chemistry manuals.
B. Spectroscopy	When a beam of sunlight is passed through a prism or a diffraction grating, the complete rainbow is formed with one color blending into the next.	Pass a narrow beam of sun light through a prism to obtain a continuous spectrum.
	A line spectrum contains narrow bands of light energy which represent some parts of a continuous spectrum.	
	When elements or their compounds are sufficiently excited in their vapor phase, they yield radiant energy which forms the characteristic spectral lines used to identify each element.	Look through a spectroscope to see the line spectrum produced by excited gases in a discharge tube. Directions for making a spectroscope are given in A 8.04 and for setting up a discharge tube in CH 2.17-c. In a darkened room pupils can see the line spectrum of a gas in a discharge tube by looking through

erstandings d Concepts	Laboratory Experiences	Suplementary Information
of some ions can ted by succes- ipitation.	Use the separation of Group I (Ag^+, Hg^{++}, and Pb^{++}) to show successive precipitations. Directions can be found in most analytic chemistry manuals.	The use of hydrogen sulfide to precipitate sulfides is not recommended. H_2S is more poisonous than CO.
eam of sunlight d through a prism fraction grating, ete rainbow is th one color into the next.	Pass a narrow beam of sunlight through a prism to obtain a continuous spectrum.	Because of its speed and accuracy, spectroscopy has become one of the most important analytical methods.
ectrum contains nds of light en- h represent some a continuous		Each color line in the line spectrum represents a discrete amount of energy.
ents or their are sufficient- d in their vapor ey yield radiant ich forms the istic spectral d to identify ent.	Look through a spectroscope to see the line spectrum produced by excited gases in a discharge tube. Directions for making a spectroscope are given in A 8.04 and for setting up a discharge tube in CH 2.17-c. In a darkened room pupils can see the line spectrum of a gas in a discharge tube by looking through	*The excited atom is discussed in Unit I, Section IV A 3.* Electrons may be excited by heating the elements or their compounds in a flame, by exposing them to light, or by enclosing their gaseous phase between the high voltage terminals of a discharge tube. Usually discharge tubes can be found in physics laboratories.

Topical Outline	Understandings and Concepts	Laboratory E
		replicas of d gratings moun
	Some vaporized materials give off a limited set of wave frequencies (colors) to which the eye is sensitive. A crude spectroscopic analysis can be made by identifying the color of the flame in which the material is being vaporized.	Pupils can id known ions by they impart t 8.05 lists so mixtures.
C. Chromatography	Chromatography is a process by which the components of a mixture are separated from a fixed or stationary phase by a moving phase.	Emphasis shoul on the use of raphy techniqu
1. Phases	The fixed phase may consist of a column of finely divided solid or a liquid held on a firm support.	Inspect the sur some marble chi have been immer per sulfate. A to explain why color doesn't "
	The moving phase may consist of a liquid or gaseous solvent.	Place the end o of filter paper and watch the li

tandings oncepts	Laboratory Experiences	Suplementary Information
	replicas of diffraction gratings mounted in glass.	
ed materials imited set of cies (colors) eye is sen- rude spectro- sis can be tifying the flame in terial is be- d.	Pupils can identify unknown ions by the colors they impart to flames. A 8.05 lists some unknown mixtures.	Color interference produced by the presence of some ions can be reduced by the use of appropriate filters. *Pupils are not expected to memorize the colors imparted to flames but are expected to interpret the results of laboratory tests on the basis of reference charts.*
hy is a pro- n the compo- ixture are om a fixed or ase by a	Emphasis should be placed on the use of chromatography techniques.	Chromatographic separations of mixtures are of primary importance in industry today. Chromatography has made many analytical procedures obsolete since chromatographic separations generally can be obtained more rapidly.
se may con- umn of finely or a liquid m support.	Inspect the surface of some marble chips which have been immersed in copper sulfate. Ask pupils to explain why the blue color doesn't "wash off."	Often the fixed phase is called the adsorbent.
ase may con- uid or gas-	Place the end of a strip of filter paper in water, and watch the liquid move	Other names for the moving phase are "eluent," "sol-

Topical Outline	Understandings and Concepts	Laboratory Experiences
		up the paper. Compare speed of the moving wat with that of other solvents moving up other strips of filter paper
	There is no way to predict the best choice of phases for a particular separation. They must be worked out by trial and error.	A 8.06 and A 8.07 can b used to show solvent - sorbent component relationships
2. Rate of flow	The components of the mixture move along the fixed phase at different velocities. The velocities of the components vary directly with their solubilities in the liquid phase and inversely with their sorption in the fixed phase. Substances can be identified by their rate of flow factor, R_f.	

andings ncepts	Laboratory Experiences	Suplementary Information
	up the paper. Compare the speed of the moving water with that of other solvents moving up other strips of filter paper	vent," "solvent system," and "developing solvent." The moving phase may contain more than one substance. A description of gas chromatography is given in CH 3.44.
ay to pre- choice of particular They must by trial	A 8.06 and A 8.07 can be used to show solvent - adsorbent component relationships	
s of the along the at different		
es of the ary directly olubilities phase and h their he fixed		
n be identi- rate of R_f.		

Topical Outline	Understandings and Concepts	Laboratory Ex
	The R_f factor is derived from the distance the eluent and substance travel along the fixed phase. $R_f = \frac{\text{Distance a component moves}}{\text{Distance eluent moves}}$	See A 8.08 for an R_f referenc Have pupils id "spots" on pap grams by deter R_f values and t the table made
3. Identification	Often substances are identified by the R_f factor for the absorbent-solvent system.	Develop chromat the same substa ious solvents a the R_f values ob

derstandings nd Concepts	Laboratory Experiences	Supplementary Information
factor is derived e distance the and substance along the fixed nce a component moves nce eluent moves	See A 8.08 for developing an R_f reference table. Have pupils identify "spots" on paper chromatograms by determining the R_f values and then using the table made in A 8.08.	When an R_f factor indicates the possible presence of a specific substance, make a confirmation test: place a drop of the unknown on the starting line near the spot of the specific substance, and run a chromatogram. If the known and unknown are identical, the two spots will be alike and equally distant from the starting line. Additional proof can be obtained by varying the solvents and adsorbents in making the chromatograms. R_f values can be affected by the concentration of the components and impurities in the solvent. Use the techniques listed above to verify results. *Pupils will be expected to use and interpret R_f reference tables found in texts.*
ubstances are iden- y the R_f factor absorbent-solvent	Develop chromatograms of the same substance in various solvents and compare the R_f values obtained.	R_f tables for solvent-absorbent systems are found in chromatography texts. *See the Biblio-*

Topical Outline	Understandings and Concepts	Laboratory Experiences
	Some substances are identified as colored bands or spots on the fixed phase.	
	Colorless components may be identified by spraying the chromatogram with chemicals producing a color change or fluorescence.	Find the fingerprints "left" on filter paper. Spray the paper with ninhydrin and gently warm the paper. Various shades of purple will appear where amino acids were left by the fingers.
	Some substances may be identified within the moving phase as it leaves the fixed phase.	
4. Adsorption	Components of some mixtures can be adsorbed or fastened to the fixed phase.	Separate the chlorophylls from plants by using an adsorption column. See Activity CH 3.43 c.

standings Concepts	Laboratory Experiences	Supplementary Information
		graphy in Appendix B.
ances are iden- colored bands or he fixed phase.		If two substances form a single spot in the solvent, separation generally can be achieved by the use of a second solvent.
components may ied by spraying togram with chem- ucing a color fluorescence.	Find the fingerprints "left" on filter paper. Spray the paper with ninhydrin and gently warm the paper. Various shades of purple will appear where amino acids were left by the fingers.	Two-dimensional chromatography first separates "groups" and then by changing the solvent and the direction of its flow separates out the components of the groups. Amino acids are generally separated by two-dimensional chromatography on paper or a thin film.
ances may be within the se as it leaves phase.		If samples of solvent are collected as it flows from a column or drips from the end of a filter paper, the faster moving components can be found in the solvent while other components are still bound to the adsorbent.
of some mixtures rbed or fastened d phase.	Separate the chlorophylls from plants by using an adsorption column. See Activity CH 3.43 c.	Adsorbents are generally oxides, hydrated oxides, and salts.

Topical Outline	Understandings and Concepts	Laboratory
	The liquid phase also can be adsorbed on the fixed phase. The moving phase and the components of the mixture compete for adsorption sides on the fixed phase. The competition results in the components moving along the fixed phase at different velocities. Thus, the components are separated.	
5. Thin layer	Thin films of a gel or "activated" adsorbent fixed to a support such as glass or plastic are faster and easier to use than columns or paper separations.	Directions for T found in A 8.09. Amino acid separa silica gel layers described in A 8.

tandings oncepts	Laboratory Experiences	Supplementary Information
phase also can on the fixed		
phase and the of the mixture adsorption e fixed phase. tion results in nts moving along hase at differ- ies. Thus, the are separated.		There are several factors that affect the degree of adsorption. Some factors are the natures of the adsorbent, the solvent, and the components of the mixture, and the surface area of the adsorbent. The components which are bound more strongly to the adsorbent move less rapidly along the fixed phase than the components which are held loosely to the adsorbent. Generally, the more powerful or active an adsorbent is, the more powerful or active an eluent must be in order to move components through the fixed phase.
of a gel or adsorbent support such as astic are faster to use than paper separa-	Directions for TLC can be found in A 8.09. Amino acid separations on silica gel layers are described in A 8.10.	The term, TLC, refers to thin layer chromatography. Both adsorption and partition chromatography can be carried out on thin films.

Topical Outline	Understandings and Concepts	Laboratory Experiences
	Thin films are made by spreading a thin layer of a slurry of adsorbent in a suitable solvent over a plate of glass or a sheet of plastic. The film is dried, usually in an oven. Before use, the film must be exposed to air so that water vapor may become bonded onto the adsorbent. The hydration activates the adsorbent.	
D. Gas evolution	Some substances can be identified by reactions producing a characteristic gas.	Pupils can identify bicarbonate, carbonate, ammonium, sulfide and/or sulfite compounds in a group of unknown samples. Most laboratory manuals show laboratory apparatus set-ups for these tests.
	An acid and a carbonate or a bicarbonate will form CO_2 gas. . CO_2 turns limewater milky.	
	An acid and a sulfite will form SO_2 gas. . SO_2 turns purple $KMnO_4$ solution to colorless.	

ndings cepts	Laboratory Experiences	Supplementary Information
e made by hin layer of dsorbent in lvent over a s or a sheet The film is y in an oven. he film must air so that ay become he adsorbent. activates .		Silica gel is one of the substances most commonly used to make thin films. "G" grade indicates that an adsorbent contains plaster of paris to help hold it to the support.
es can be reactions haracteristic carbonate or will form limewater sulfite will purple $KMnO_4$ to colorless.	Pupils can identify bicarbonate, carbonate, ammonium, sulfide and/or sulfite compounds in a group of unknown samples. Most laboratory manuals show laboratory apparatus setups for these tests.	A fume hood should be used in carrying out tests forming gases. The generator should be taped or wrapped with a towel and a thistle tube used for the addition of the acid if the gas is to be bubbled into the test solution.

Topical Outline	Understandings and Concepts	Laboratory Experien
	An acid and a sulfide will form H_2S gas. . H_2S turns moist lead acetate paper black.	Restrict testing of moist lead acetate p and use only small q tities of unknown sa If the reaction is c out in a test tube, drop of testing solu on the end of a stir rod can be used to i tify the gas. The l method uses only a s amount of sample and duces a small quanti gas.
	NaOH solution or solid $Ca(OH)_2$ and an ammonium compound will produce NH_3 gas. . NH_3 turns moist red litmus blue.	
II. Quantitative Analysis	Quantitative analysis measures only the amount of a specific component. The techniques of quantitative analysis must keep loss of the desired component to a minimum.	

nderstandings and Concepts	Laboratory Experiences	Supplementary Information
d and a sulfide will $_2$S gas. S turns moist lead etate paper black.	Restrict testing of H_2S to moist lead acetate paper and use only small quantities of unknown samples. If the reaction is carried out in a test tube, a large drop of testing solution on the end of a stirring rod can be used to identify the gas. The latter method uses only a small amount of sample and produces a small quantity of gas.	Hydrogen sulfide gas is extremely poisonous.
olution or solid 2 and an ammonium nd will produce NH_3 3 turns moist red tmus blue.		Ammonia gas reacts to some degree with water to form NH_4^+ and OH^-. $NH_3 + HOH = NH_4^+ + OH^-$ When NaOH solution is used as a reactant, gentle heat may be needed to liberate the gas.
tative analysis es only the amount pecific component.		Quantitative analysis uses reactions resulting in the formation of a product that can be isolated.
chniques of quanti- analysis must keep f the desired compo- o a minimum.		Much of industry's quantitative analysis is done by instrument analysis.

Topical Outline	Understandings and Concepts	Laboratory Expe
	The precision of quantitative analysis results is determined by the limitations of the equipment used.	Have pupils use b with different se ities to determin mass of a few str thread or grains Compare the resul account for the d ences.
A. Gravimetric methods	A direct gravimetric method measures the mass of the component of interest.	Directions for fi percentage compos various substance found in most hig laboratory manual
	An indirect method measures the loss of mass due to a volatile species escaping.	
B. Volumetric methods		
1. Gas measurement	Gas analysis measures the volume of a gas produced or consumed.	Measure the amoun produced by bakin or effervescing t and powders used tralize stomach a A 8.11.
2. Titrating normal solutions	Titrations are used to find the volume of a standard solution that is chemically equivalent to that	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
e precision of quantita- ve analysis results is termined by the limita- ons of the equipment ed.	Have pupils use balances with different sensitivities to determine the mass of a few strands of thread or grains of sand. Compare the results and account for the differences.	
direct gravimetric thod measures the mass the component of inter- t.	Directions for finding the percentage composition of various substances can be found in most high school laboratory manuals.	
indirect method mea- res the loss of mass due a volatile species caping.		Finding the percent of water in a hydrated crystal requires the use of the indirect method of measurement.
s analysis measures the lume of a gas produced consumed.	Measure the amount of CO_2 produced by baking powders or effervescing tablets and powders used to neutralize stomach acid. See A 8.11.	Point out that pressure and temperature have an effect on the accuracy of measuring volumes of gases. *Pupils are not required to know how to convert gas measurements to STP.*
trations are used to nd the volume of a stan- rd solution that is chem- ally equivalent to that		

Topical Outline	Understandings and Concepts	Laboratory Experienc
	of an unknown solution.	
	The normality (N) of a solution is the number of gram equivalents of solute in a liter of solution.	Pupils should be able prepare a specified v of a solution with a inite normality.
	. One gram equivalent of an acid is the mass in grams that furnishes 1 mole (1 g.) of hydrogen ions.	
	. One mole of an acid or base contains 1 or more moles of hydrogen or hydroxide ions.	
	. One gram equivalent of a base is the mass in grams that furnishes 1 mole (17 g.) of hydroxide ions.	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
of an unknown solution.		
The normality (N) of a solution is the number of gram equivalents of solute in a liter of solution.	Pupils should be able to prepare a specified volume of a solution with a definite normality.	*For a specific reaction, gram equivalents can be based upon any ion. However, pupils will be responsible only for gram equivalents of acids, based on the hydrogen ion equivalent, and of bases, based on the hydroxide ion equivalent.*
. One gram equivalent of an acid is the mass in grams that furnishes 1 mole (1 g.) of hydrogen ions.		
. One mole of an acid or base contains 1 or more moles of hydrogen or hydroxide ions.		One mole of HCl contains only 1 mole of hydrogen ions; one mole of H_2SO_4 has 2 moles of hydrogen ions; and one mole of H_3PO_4 yields 3 moles of hydrogen ions.
		An acid which contains 2 moles of hydrogen ions per mole of acid is called a diprotic acid.
. One gram equivalent of a base is the mass in grams that furnishes 1 mole (17 g.) of hydroxide ions.		A base which contains 2 moles of hydroxide ions per mole of base is called a dihydroxy base.

Topical Outline	Understandings and Concepts	Laborator
	The normality of an acid or base can be determined by slowly combining it with a base or acid of known normality (standard solution) until neutralization occurs. This process is called titration. The end point of the titration may be determined by the use of appropriate indicators.	Titration given in m manuals.
	The normality of the unknown solution can be calculated from the following equation: Volume of unknown solution x its normality = volume of known solution x its normality.	Determine acetic aci kinds of amount of antacid pr neutralize.
C. Instrument analysis		
1. pH meters	Many titrations involve bringing a solution to a specific pH.	

Understandings and Concepts	Laboratory Experiences	Supplementary Information
normality of an acid ase can be determined lowly combining it a base or acid of n normality (standard tion) until neutral- ion occurs. This pro- is called titration.	Titration exercises are given in most laboratory manuals.	
end point of the titra- may be determined by use of appropriate cators.		The end point of the titration can be determined by temperature changes or electrode potential changes. End points determined by the above methods are achieved by instrument analysis.
normality of the own solution can be ulated from the follow- equation: lume of unknown solu- on x its normality = lume of known solution its normality.	Determine the amount of acetic acid in different kinds of vinegar or the amount of acid a stomach antacid preparation can neutralize.	
titrations involve ging a solution to a ific pH.		

Topical Outline	Understandings and Concepts	Laboratory Experi
	The pH scale can be used to express the strength of an acid or base.	
	. A pH 7 indicates a neutral solution containing equal concentrations of hydrogen ions and hydroxide ions.	Compare the colors versal indicator i ious acid, base, a solutions with the scale for the indi
	. A pH under 7 indicates that there are more hydrogen ions than hydroxide ions in the solution.	
	. As the concentration of hydrogen ions increases, the pH decreases.	
	. A pH greater than 7 indicates that there are more hydroxide ions than hydrogen ions in the solution.	
	. As the concentration of the hydroxide ions increases, the pH increases.	
	A pH meter measures the pH of a solution more accurately than indicators	If a pH meter is a have the pupils do acid-base titratio

standings Concepts	Laboratory Experiences	Supplementary Information
le can be used the strength of base.		*Pupils are not expected to become involved with the calculation of pH from the negative log of the hydrogen ion concentration.*
ndicates a neu- ution containing ncentrations of ions and hydrox- .	Compare the colors of universal indicator in various acid, base, and salt solutions with the pH color scale for the indicator.	Point out that an indicator changes color at a pH specific for the indicator. Not all indicators change at a pH of 7.
ler 7 indicates re are more ions than le ions in the .		
oncentration of ions increases, lecreases.		
eater than 7 indi- at there are droxide ions than ions in the .		
concentration of roxide ions es, the pH es.		
r measures the lution more y than indicators	If a pH meter is available, have the pupils do an acid-base titration.	The pH meter depends upon electrode potential changes. The instrument

Topical Outline	Understandings and Concepts	Laboratory Experiences
	do.	Compare the results with those obtained by using phenolphthalein and methyl orange indicators.
2. Colorimeters and spectrophotometers	Upon dissolving, some substances form colored solutions.	
	The depth of color of a solution increases as the concentration of the solute increases.	Compare the colors of a series of known dilutions of copper sulfate or potassium permanganate. Directions for making the dilutions are found in A 8.12.
	As light is passed through a solution, some light is absorbed and the rest is transmitted.	Determine the concentration of a solution by matching it against equal volumes of the series prepared above.
	The amount of light transmitted through a solution can be measured by a photoelectric cell in instruments known as colorimeters or spectrophotometers.	

standings Concepts	Laboratory Experiences	Supplementary Information
	Compare the results with those obtained by using phenolphthalein and methyl orange indicators.	can be used successively by pupils.
lving, some sub- rm colored solu-		
of color of a ncreases as the ion of the sol- ses.	Compare the colors of a series of known dilutions of copper sulfate or potassium permanganate. Directions for making the dilutions are found in A 8.12.	
s passed through n, some light is and the rest is ed.	Determine the concentration of a solution by matching it against equal volumes of the series prepared above.	The most simple form of colorimeter is based on matching an unknown with a known standard.
t of light trans- rough a solution asured by a tric cell in ts known as color- r spectrophotome-		A photoelectric cell changes light energy into electrical energy. As the amount of light falling on a photoelectric cell increases, the electrical current in the circuit increases. Specific frequencies of light absorbed or transmitted can be measured by

Topical Outlines	Understandings and Concepts	Laboratory Experienc
	By comparing the amount of transmission or absorption with that of standard solutions of the solute, the unknown concentration of solute in a given solution can be determined.	

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placing colored filters, a prism, or a diffraction grating in the optical system.

Generally, the transmission of a series of known dilutions of a specific solute is plotted to make a standardized transmission-concentration graph. After determining the amount of transmission, the technician can read the concentration of a solution from the standardized graph.

If a spectrophotometer or colorimeter is available, the teacher may wish to develop this section in depth.

APPENDIX A - LABORATORY ACTIVITIES

A 1.01 Change of Phase

Insert a thermometer into the two-hole stopper of a distilling flask
sition the thermometer bulb will be opposite the delivery tube arm of
flask which is supported on an iron ring stand. Put the stopper with
the water. Pupils should observe that the "steam" coming from the ar
The true steam is the invisible gas between the boiling water and the

A 1.02 Long Form of the Periodic Table

Pupils may be interested in deriving a long form Periodic Table. Div
an adding machine into 104 1-inch wide boxes. Starting at the left e
from 1 to 104.

Pass out an alphabetical list of all the elements (except the transit
arrangement and atomic number for each. Instruct the pupils to refer
in any box on their paper strip that has a number equal to the atomic
1 electron in its highest principal energy level. Use another mark t
elements with only 8 electrons in their highest principal energy leve

Use masking tape to fasten the left edge of the strip to the upper le
of paper, manila folder, or desk top. Cutting the strip where necess
so that the same kind of marked boxes are under each other. Remind p
as one reads from left to right or top to bottom. The strips will no
their unequal lengths.

In order to "flatten" the chart, cut between the two boxes of the firs
enough so that box 10 of the second row can be located directly under
out. Pupils will see the necessity for further cutting and shifting t
shift appears necessary, point out that the table will become too large
section could be cut out and fastened "down below." When the arrangem
periods (horizontal rows) and groups (vertical columns). Insert symbo
by the "cutout sections."

If the table is fastened inside a manila folder, students can convenie
Periodic Tables and add additional information about the elements as i
year.

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o-hole stopper of a distilling flask so that when the stopper is in po- be opposite the delivery tube arm of the flask. Pour some water into a ron ring stand. Put the stopper with the thermometer in place, and boil e that the "steam" coming from the arm is really a fog of condensed steam. gas between the boiling water and the condensed fog.

ving a long form Periodic Table. Divide a 9-foot strip of paper from h wide boxes. Starting at the left end of the strip, number the sections

all the elements (except the transition elements), giving the electronic r each. Instruct the pupils to refer to the list and to place a "1" that has a number equal to the atomic number of an element that has only pal energy level. Use another mark to identify boxes representing n their highest principal energy level.

eft edge of the strip to the upper left-hand corner of a large sheet top. Cutting the strip where necessary, pupils should arrange the strip boxes are under each other. Remind pupils that the numbers must increase or top to bottom. The strips will not be flat but will form loops due to

cut between the two boxes of the first strip, and shift box 2 over far ond row can be located directly under it when the second row is flattened ity for further cutting and shifting to straighten row 4. When another t that the table will become too large for convenient use and that a tened "down below." When the arrangement has been completed, number the oups (vertical columns). Insert symbols, and label the series represented

a manila folder, students can conveniently keep their own "homemade" al information about the elements as it is taught throughout the school

---

A 2.01 Reactions Between Aqueous Solutions

An interesting laboratory problem can arise from mixing equal volumes
from a number of prepared solutions, and identifying any products resul
two solutions.

Direct pupils to find as many reacting combinations as they can within
a few ground rules concerning the amounts of solutions to be used and t
tion before starting another.

Some diluted aqueous solutions that provide a wide range of reactions a
$BaCl_2$, $CuSO_4$, $AgNO_3$, K_2CO_3, NaOH, and $FeCl_3$.

A 2.02 Quicklime from Limestone

Place a few small pieces of marble or limestone on a wire screen suppor
burner under the screen, and adjust the support so that the screen cross
cone. Heat the limestone intensely with the burner for 15 to 20 minute
their appearance with pieces of the original unheated limestone. Add w
dropper or pipette to both heated and unheated samples. Note any evide

If pupils need further evidence that a chemical change has occurred dur
test both heated and unheated pieces with wet red or neutral litmus. N
turns the litmus blue.

A 2.03 Reading Labels on Reagent Bottles

Display a number of bottles of reagents, each labeled with the appropri
as CuS, $CuSO_3$, $CuSO_4$, $NaHCO_3$, Na_2CO_3, MgO, HgO, $FeCl_2$, and $FeCl_3$.

Ask the pupils to select the bottles containing any reagent, the name o
as part of the laboratory work.

Pupils can develop skills in recognition of formulas as well as in unde
reading of labels during the selections of chemicals.

A 2.04 Adapting Feltboard Techniques

The feltboard techniques described in CH 1.17 and CH 1.18 can be used b
Substitute small circles of colored construction paper for felt circles

arise from mixing equal volumes of aqueous solutions, two at a time, and identifying any products resulting from the interaction of the

g combinations as they can within a given period of time. Establish unts of solutions to be used and the need for completing one combina-

rovide a wide range of reactions are: $Pb(NO_3)_2$, KI, HCl, $MgSO_4$, $\text{F [illegible] Cl}_3$.

limestone on a wire screen supported by a ringstand. Set a Bunsen e support so that the screen crosses the point of the blue inner ith the burner for 15 to 20 minutes. Cool the pieces, and compare riginal unheated limestone. Add water drop by drop with a medicine unheated samples. Note any evidence of chemical reaction.

a chemical change has occurred during the heating of the limestone, with wet red [illegible] neutral litmus. Notice that the heated limestone

ts, each labeled with the appropriate formula. Include such items MgO, HgO, $FeCl_2$, and $FeCl_3$.

containing any reagent, the name of which appears on a list given

ion of formulas as well as in understanding the need for careful ns of chemicals.

CH 1.17 and CH 1.18 can be used by pupils doing individual work. onstruction paper for felt circles and a piece of cardboard for the feltboard. The colored papers can be fastened to the cardboard tape.

A manila folder can be used not only for the cardboard but also for

The substitute materials can be used in the same manner as feltboard

A 2.05 Combining Mole Ratio

Make up 100 ml. of a 1 molar solution of NaOH and 100 ml. of a 1 mola Label each solution 0.001 moles/ml.

Pour 10 ml. of the base into each of three test tubes. To the first 10 ml.; and to the third, add 20 ml. of the acid.

Stir the solution in each test tube, and test its pH using a few ml. of Point out that an acid neutralizes a base. Ask the pupils which test

Calculate the number of moles of acid put as a solute into each test

$$\text{vol. (ml.)} \quad \frac{\text{x moles}}{\text{ml.}} = \text{moles acid u}$$

Find the apparent mole-combining ratio involved in this reaction.

A 3.01 Regular Tetrahedron

From strips of cardboard, cut four equilateral triangles 4 inches on e tape to make a tetrahedron.

A 4.01 Changing Alkanes to Alcohol

a. Build a model of a methane molecule and an -OH functional group. A group can be put on the methane molecule to form methyl alcohol. O the functional group must be substituted for a hydrogen atom, go on papers can be fastened to the cardboard by pins, thumbtacks, or bits of masking

not only for the cardboard but also for storing the materials.

be used in the same manner as feltboard materials.

solution of NaOH and 100 ml. of a 1 molar solution of hydrochloric acid.
les/ml.

each of three test tubes. To the first test tube, add 5 ml.; to the second
20 ml. of the acid.

st tube, and test its pH using a few ml. of universal indicator solution.
alizes a base. Ask the pupils which test tube contains the neutral solution.

s of acid put as a solute into each test tube containing the base:

$$\text{vol. (ml.)}\ \frac{\text{x moles}}{\text{ml.}} = \text{moles acid used}$$

ning ratio involved in this reaction.

---

t four equilateral triangles 4 inches on each side. Assemble with cellulose

---

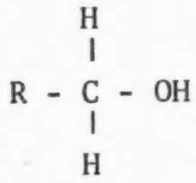
ne molecule and an -OH functional group. Ask the pupils how the functional
methane molecule to form methyl alcohol. Once the pupils understand that
t be substituted for a hydrogen atom, go on to part b.

b. Set up a problem: Using no more than one -OH group on a carb
ble from the first five members of the alkanes. Record the s
Keep all structural formulas for alcohols containing the same
those with other carbon counts in corresponding columns.

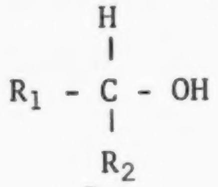
Pupils should discover straight chain (normal) alcohols, isomers
which is not an "end" carbon, and those containing more than one

In discussing the results, organize their findings, as:

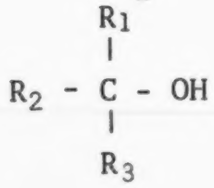
Types by number of R's:

Primary alcohols 

$$\mathrm{R}-\overset{\overset{\displaystyle \mathrm{H}}{|}}{\underset{\underset{\displaystyle \mathrm{H}}{|}}{\mathrm{C}}}-\mathrm{OH}$$

Secondary 

$$\mathrm{R_1}-\overset{\overset{\displaystyle \mathrm{H}}{|}}{\underset{\underset{\displaystyle \mathrm{R_2}}{|}}{\mathrm{C}}}-\mathrm{OH}$$

Tertiary 

$$\mathrm{R_2}-\overset{\overset{\displaystyle \mathrm{R_1}}{|}}{\underset{\underset{\displaystyle \mathrm{R_3}}{|}}{\mathrm{C}}}-\mathrm{OH}$$

A 4.02 Solubilities of Alcohols

The use of semimicro techniques can reduce the concentration of
tribute to the safety aspect of the laboratory experience.

Into each of four test tubes, put 10 drops of water. To each tu
one in each test tube. Ethanol, n-propanol, 2-propanol, n-butan
for use.

Compare the depth of any immiscible layers. The least soluble a
"alcohol layer."

e than one -OH group on a carbon atom, make as many alcohols as possi- of the alkanes. Record the structural formula representing each model. r alcohols containing the same number of carbon atoms in one column, in corresponding columns.

in (normal) alcohols, isomers in which the -OH is on a carbon atom hose containing more than one functional group.

their findings, as:

Types by number of -OH groups:

Monohydroxy 1 -OH

Dihydroxy 2 -OH groups

Trihydroxy 3 -OH groups

reduce the concentration of volatile vapors from alcohols and con- laboratory experience.

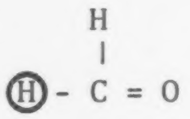
0 drops of water. To each tube, add 10 drops of an alcohol, a different propanol, 2-propanol, n-butanol, glycerol, and n-pentanol are suitable

layers. The least soluble alcohol will have the grestest depth of

A 4.03 Oxidation of a Primary Alcohol - Formation of Aldehyde Group

Have the pupils make a methanol model, and take out some oxygen "a
to change the model so it has one C, two H, and one O atom. Obser
C, and 2 for O. Pupils will note that two hydrogen atoms are remo
be removed. The extra O atoms taken from the box should give a hi
formaldehyde.

Show a homologous series



$$\text{Ⓗ} - \overset{\overset{H}{|}}{C} = O$$

Remove the hydrogen indicated in the diagram and substitute alkane
propanal, and butanal will be formed. This should develop a gener

A 4.04 Oxidation of a Secondary Alcohol - Formation of Ketone Group

Start with a model of 2-propanol and some oxygen "atoms." Have th
model to represent a composition of C_3H_6O. The final model may n
C atom where the O is attached. Ask the pupils to indicate what h
added. By changing the length of the carbon chains, the homologous

A 4.05 Oxidation of an Aldehyde

Prepare an oxidizing agent of 1 g. $KMnO_4$/100 ml.H_2O. To 15-20 ml
of acetaldehyde. The odor of vinegar should be observed. Warm th
necessary.

A 4.06 Oxidation To Form a Carboxylic Group, Using Models

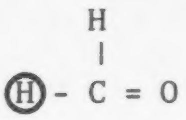
Ask pupils to change a model of CH_4 to CH_2O_2. The only restricti
is that two oxygen atoms cannot bond together. Show that HCOOH i
adding carbon chains in place of the hydrogen on the carbon atom.

The preparation of an acid by oxidation of a primary alcohol can
CH_3OH and changing it to HCOOH. Hydrogen must be removed, and oxy
reaction.

y Alcohol - Formation of Aldehyde Group

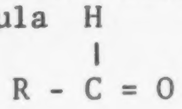
a methanol model, and take out some oxygen "atom" balls from the kit. Ask the pupils
o it has one C, two H, and one O atom. Observe bonding requirements: 1 for H, 4 for
ls will note that two hydrogen atoms are removed. Ask for a possible way these could
a O atoms taken from the box should give a hint. The substance formed, HCHO, is

ies



$\overset{H}{\underset{|}{}}$ Ⓗ - C = O

ndicated in the diagram and substitute alkane chains of 1, 2, and 3 carbons. Ethanal,
will be formed. This should develop a general aldehyde formula



$R - \overset{\overset{H}{|}}{C} = O$

lary Alcohol - Formation of Ketone Group

f 2-propanol and some oxygen "atoms." Have the pupils figure out how to change the
composition of C_3H_6O. The final model may not have an H atom on the oxygen or the
attached. Ask the pupils to indicate what had to be removed and what needed to be
he length of the carbon chains, the homologous series can be shown.

hyde

agent of 1 g. $KMnO_4$/100 ml.H_2O. To 15-20 ml. of the oxidizing solution, add 10 drops
odor of vinegar should be observed. Warm the solution in a hot water bath if

Carboxylic Group, Using Models

a model of CH_4 to CH_2O_2. The only restriction other than usual bond requirements
oms cannot bond together. Show that HCOOH is the start of a homologous series by
in place of the hydrogen on the carbon atom.

acid by oxidation of a primary alcohol can be shown by starting with a model of
to HCOOH. Hydrogen must be removed, and oxygen added. This is an oxidation

Normal alcohol $\xrightarrow[\text{oxidation}]{\text{partial}}$ aldehyde $\xrightarrow{\text{oxidation}}$ acid.

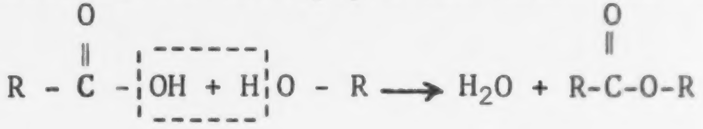
A 4.07 Esterification

Have models of methanol and methanoic (formic) acid available.

Ask pupils to combine the two molecules by removing only two hydrogen atoms a molecule of water.

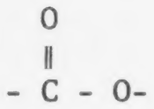
Some pupils will use the OH of the alcohol; others, the OH of the acid. Th pupils of the function of tagged atoms.

By use of a radioactive isotope, it was found that the reaction proceeded:



$$\mathrm{R-\overset{\overset{\displaystyle O}{\|}}{C}-\boxed{OH + H}O-R \longrightarrow H_2O + R-\overset{\overset{\displaystyle O}{\|}}{C}-O-R}$$

Pupils should note that



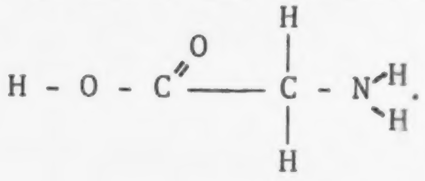
$$\mathrm{-\overset{\overset{\displaystyle O}{\|}}{C}-O-}$$

is the functional group of esters. (A

A 4.08 Amine Group

a. Make a model of an NH_3 molecule. Remove one hydrogen atom. The result amine group $-\mathrm{N}\genfrac{}{}{0pt}{}{\mathrm{H}}{\mathrm{H}}$. Attach alkane carbon chains to show the formation of

b. Make a model of



$$\mathrm{H-O-\overset{O}{\overset{\|}{C}}-\underset{\underset{\displaystyle H}{|}}{\overset{\overset{\displaystyle H}{|}}{C}}-N\genfrac{}{}{0pt}{}{H}{H}}$$

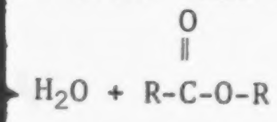
. Point out that structures si functional groups, a carboxylic group and an amine group. The combinat oxidation $\rightarrow$ acid.

ic (formic) acid available.

ules by removing only two hydrogen atoms and one oxygen atom to form

alcohol; others, the OH of the acid. This is an opportunity to inform
oms.

was found that the reaction proceeded:

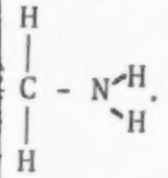


$$\rightarrow H_2O + R\text{-}\overset{\overset{\displaystyle O}{\|}}{C}\text{-}O\text{-}R$$

is the functional group of esters. (A memory device - "Esters coo")

Remove one hydrogen atom. The resulting functional group is an

carbon chains to show the formation of amine compounds.

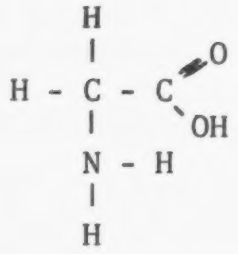


$$\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}} - N\begin{smallmatrix} \nearrow H \\ \searrow H \end{smallmatrix}$$

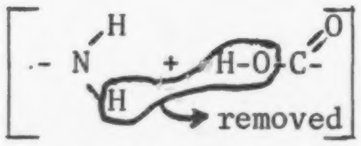
. Point out that structures similar to this contain two

group and an amine group. The combination makes an amino acid molecule.

A 4.09 Amide Linkage

Start with two molecules of  $\mathrm{H{-}C(H)(NH_2){-}C(=O)OH}$ (glycine). Arrang

one faces the amide ending of the other. Connect the two models b



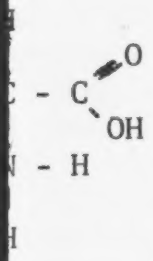
A dipeptide with an amide linkage has been formed. By using a thi tide can be formed.

If each pupil makes a model of a different amino acid, a "protein" together by removal of H_2O and establishment of an amide linkage.

A 4.10 Glyceride Structures

By an esterification process (A 4.07), join an ethanoic acid molec erol model and methanoic acid molecules to each of the two remaini sulting model represents an ester of glycerol called a glyceride.

Extend the carbon chain of the acetate (an ethanoic acid group) to If chains of from 12-18 carbons are also put on the other "acid" c result.



(glycine). Arrange the models so the carboxylic group of

ther. Connect the two models by removing a water molecule.

as been formed. By using a third molecule of glycine, a longer pep-

ifferent amino acid, a "protein" can be formed by joining the models
ablishment of an amide linkage.

07), join an ethanoic acid molecule model to one -OH group of a glyc-
cules to each of the two remaining -OH groups of glycerol. The re-
of glycerol called a glyceride.

tate (an ethanoic acid group) to 12 carbons (if balls are available).
e also put on the other "acid" chains, a fatty glyceride molecule would

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A 5.01 Effect of Heat on the Enzyme, Rennin

Crush a Junket tablet (rennin source), and dissolve it in 10 ml. of dist solution in a water bath for 5-10 minutes, then cool the solution to roo

Crush and dissolve a Junket tablet in 10 ml. of distilled water (room te

Into each of two test tubes, place 20 ml. of warm milk (25-30°C.). To th heated enzyme solution, and to the other tube 1 ml. of the unheated enzy for the milk to "set into a pudding." Because of heat destruction of th not occur in the milk that contains the heated junket tablet.

The "coagulating effect" of the enzyme, rennin, is really coagulation of

A 5.02 Stages of Boiling Syrup

Boiling a sugar solution causes a solution of simple sugars to be formed ratio increases, the syrup assumes various "stages."

Add 100 g. of sugar to 60 ml. of hot water in a 250-ml. beaker. Stir th dissolved. Suspend a thermometer from a clamp and adjust the position o centered in the solution. Heat the solution over a low flame, and record solution begins to boil. When the solution reaches 105°C., test it by p water in an evaporating dish. Describe the appearance and consistency o tinue to boil the solution, and test the solution at intervals of 5°C. b in cold water. Above 140°C., the syrup is apt to caramelize, so heating recommended.

Remind pupils that boiling syrup is much hotter than boiling water and c spilled on the skin.

The success of this exercise depends upon the absence of seed crystals o tals of sugar initially appearing on the beaker wall are "washed down." a stirring rod can be used to remove crystals.

An alternate method of testing the solution is by the use of a hydromete syrup will be necessary. Hydrometers may be found in general science an

Enzyme, Rennin

(rennin source), and dissolve it in 10 ml. of distilled water. Heat the enzyme
h for 5-10 minutes, then cool the solution to room temperature.

nket tablet in 10 ml. of distilled water (room temperature).

ubes, place 20 ml. of warm milk (25-30°C.). To the first tube, add 1 ml. of the
, and to the other tube 1 ml. of the unheated enzyme solution. Compare the time
to a pudding." Because of heat destruction of the enzyme, coagulation should
hat contains the heated junket tablet.

" of the enzyme, rennin, is really coagulation of casein, a milk protein.

p

n causes a solution of simple sugars to be formed. As the simple sugar to water
rup assumes various "stages."

60 ml. of hot water in a 250-ml. beaker. Stir the mixture until the sugar has
hermometer from a clamp and adjust the position of the thermometer so the bulb is
n. Heat the solution over a low flame, and record the temperature at which the
. When the solution reaches 105°C., test it by putting a few drops into cold
dish. Describe the appearance and consistency of the "sugar solution." Con-
ion, and test the solution at intervals of 5°C. by putting some of the solution
40°C., the syrup is apt to caramelize, so heating beyond that temperature is not

ing syrup is much hotter than boiling water and can cause very serious burns when

rcise depends upon the absence of seed crystals of sugar. Be sure that any crys-
appearing on the beaker wall are "washed down." A wet cloth around the end of
sed to remove crystals.

testing the solution is by the use of a hydrometer. Larger quantities of boiling
. Hydrometers may be found in general science and physics laboratories.

A 5.03 Hydrolysis of Proteins

a. Place two or three small pieces of hard-cooked egg white dilute HCl to the first and 15 ml. of water to the secon water and boil for 1/2 - 1 hour. Note the effect on the acid to marinating meats in vinegar solution to tenderiz

b. Meat tenderizers contain enzymes which promote the hydro tenderizer on hard-cooked egg white.

c. Remove as much flesh as possible from a joint, and boil or for 1/2 hour in a pressure cooker. Strain the liquid liquid is cooled, the gelatin formed during hydrolysis w

A 5.04 Coagulation of Proteins

a. By heat:
Remove an egg from its shell, and drop the egg into boil Boil some milk for 2-3 minutes. Let it cool.

b. By acid:
Add dilute HCl drop by drop to skim milk. As the additi proteins coagulate. Relate this activity to the souring sponsible for the curdling.

A 5.05 Coagulation of Gluten in Flour and Factors Affecting it

a. Mix enough water with flour to form a dough. Knead the d bag and tie the bag with a string. Immerse the bag in a through the dough to remove the starch. Hold the bag und the bag is clear. Open the bag and note the elastic stra

b. Pupils can compare the amount of gluten in various flours cold water and kneading all doughs for the same amount of the gluten's volume, weight, and resistance to being str

To conserve time, it is suggested this part be assigned to one of the flours.

Use samples of cake, regular pastry, graham, whole wheat,

ll pieces of hard-cooked egg white in each of two test tubes. Add 15 ml. of
t and 15 ml. of water to the second. Set the test tubes in a beaker of boiling
- 1 hour. Note the effect on the egg in each case. Relate the results of the
ts in vinegar solution to tenderize them.

in enzymes which promote the hydrolysis of the protein. Test the effect of the
ked egg white.

s possible from a joint, and boil the remaining bones and gristle for 1-2 hours
ressure cooker. Strain the liquid in which the joint was cooked. When the
gelatin formed during hydrolysis will form a gel.

shell, and drop the egg into boiling water.
minutes. Let it cool.

drop to skim milk. As the addition of acid continues, "cottage cheese"
Relate this activity to the souring of milk. Lactic acid in sour milk is re-
dling.

Flour and Factors Affecting it

flour to form a dough. Knead the dough for 2 or 3 minutes. Put it in a cloth
ith a string. Immerse the bag in a vessel of cold water and work the water
remove the starch. Hold the bag under running water until the water coming from
en the bag and note the elastic strands of gluten.

e amount of gluten in various flours by using 50 g. of a flour and 25 ml. of
ng all doughs for the same amount of time. After the starch has been washed out,
weight, and resistance to being stretched can be compared.

s suggested this part be assigned to a "team," each member being responsible for

regular pastry, graham, whole wheat, and rye flours for comparison.

c. Effect of kneading:
Prepare doughs from 50 g. of all purpose flour and 25 ml. of water. Kn
another dough for 5 minutes. Remove the starch from each and compare t

Compare the mixing method for muffins and bread listed in cookbooks.

d. Effect of sugar:
Mix a dough, and knead for 2 or 3 minutes for each of the following:
1. 50 g. flour, 65 g. sucrose, and 25 ml. H_2O
2. 50 g. flour, 15 g. sucrose, and 25 ml. H_2O
3. 50 g. flour and 25 ml. H_2O

Wash out the starch and compare gluten formation. Relate the results t
sugar in bread and cake doughs and to the textures of each.

e. Effect of liquid:
Mix two doughs, one having 50 g. flour to 25 ml. H_2O, and the other 50
each for 2-3 minutes, wash out starch, and compare gluten formation. Di
liquid in making cakes or rolls.

f. Effect of egg:
Make dough for each of the following, knead for 3-5 minutes, and wash ou
1. 50 g. flour and 25 ml. H_2O
2. 50 g. flour, 25 ml., H_2O, and 15 ml. beaten egg
3. 50 g. flour and 50 ml. beaten egg

Compare gluten formation. Discuss the effect of too much egg in batters and
parts can be quickly covered by teams, each team being responsible for one
for one mixture. Class discussion should center around a comparison of resu

A 5.06 Colloidal Properties of Starch

a. Starch and water mixture.
Add 2 grams of starch to 100 ml. of water and stir. Compare the appeara
with that of a sugar solution. Filter a few milliliters of the solution
with the original mixture.

b. Boiling starch and water mixture.
Carefully heat the remaining starch and water mixture and boil it for a
change in appearance. A test for a colloidal solution is the Tyndall te

purpose flour and 25 ml. of water. Knead one dough for 1 minute and
nove the starch from each and compare the amount of gluten.

ffins and bread listed in cookbooks.

5 minutes for each of the following:
nd 25 ml. H_2O
nd 25 ml. H_2O

gluten formation. Relate the results to the relative amounts of
nd to the textures of each.

flour to 25 ml. H_2O, and the other 50 g. flour to 40 ml. H_2O. Knead
tarch, and compare gluten formation. Discuss the effect of too much

ving, knead for 3-5 minutes, and wash out the starch:

d 15 ml. beaten egg
n egg

he effect of too much egg in batters and doughs. The last three
s, each team being responsible for one part and each pupil on a team
hould center around a comparison of results.

of water and stir. Compare the appearance of the resulting mixture
filter a few milliliters of the solution, and compare the filtrate

rch and water mixture and boil it for a minute or two. Note any
r a colloidal solution is the Tyndall test. Darken the room, and

direct a narrow beam of light through the beaker containing the
of the transmitted light with that obtained when the beam is pa
de-ionized water will show the Tyndall effect!)

c. Cool the colloidal starch solution, and note any change in cons
cules tend to form a network that "traps" the water and the gel
Relate this action to the thickening of gravy and the use of la

A 5.07 Insolubility of Lipids

a. Put 10 ml. of water into each of four test tubes. To the first
oil; to the second, a few milliliters of cooking or olive oil;
or lard; to the fourth, some oleomargarine. (A piece about the
amount of solid lipid.)

Compare their solubilities.

b. The above procedure may be repeated with vinegar. Water and vi
in cooking.

A 5.08 Emulsifying Action of Eggs and Starch

a. Place equal amounts of the following substances in four numbere
lution, starch solution, egg white diluted with an equal amount

To each test tube, add 3 drops of cottonseed oil. Shake each tub
substances remain mixed with the oil.

b. Pour 30 ml. of cooking oil and 15 ml. of vinegar into a small gl
ously. Divide the mixture into two portions. Allow one portion
that form. Add a few milliliters of egg yolk to the second port
again. Watch to see if the mixture still separates into layers.

Relate the results in these activities to the use of egg in mayo
of flour and eggs on the fat in cake.

A 5.09 Chemicals Suitable for a Baking Powder

Test the effect of water on starch, sodium bicarbonate, calcium mono
tartaric acid, calcium dihydrogen phosphate, and potassium aluminum

of light through the beaker containing the starch solution. Compare the path ght with that obtained when the beam is passed through distilled H_2O. (Tap or show the Tyndall effect!)

arch solution, and note any change in consistency of solution. The starch mole- network that "traps" the water and the gel results.
the thickening of gravy and the use of laundry starch to give "body" to fabrics.

nto each of four test tubes. To the first, add a few milliliters of cottonseed few milliliters of cooking or olive oil; to the third, a small amount of butter h, some oleomargarine. (A piece about the size of a pea should give an adequate .)

ities.

ay be repeated with vinegar. Water and vinegar are the solvents most often used

s and Starch

f the following substances in four numbered test tubes: water, dilute soap so- on, egg white diluted with an equal amount of water.

3 drops of cottonseed oil. Shake each tube vigorously, and note which of the ed with the oil.

g oil and 15 ml. of vinegar into a small glass jar, and shake the mixture vigor- xture into two portions. Allow one portion to stand, and note the two layers milliliters of egg yolk to the second portion, and shake the jar vigorously if the mixture still separates into layers.

these activities to the use of egg in mayonnaise, flour in gravy, and the effect the fat in cake.

Baking Powder

on starch, sodium bicarbonate, calcium monohydrogen phosphate, cream of tartar, hydrogen phosphate, and potassium aluminum sulfate.

Which combinations of the above materials will produce CO_2? Any combinat
make up an active ingredient of a baking powder.

A 5.10 The Role of Proteins in Leavening

Mix thoroughly 2 teaspoonfuls of cream of tartar, 1 teaspoonful of bakin
cornstarch. Divide the mixture into two equal portions in 100-ml. beaker
g. of powdered egg white, and mix well. Now add 10 ml. of water to each
Observe the nature and durability of the foam that forms in each case. T
stabilize cake batter and keep a cake from falling.

A 5.11 Controlling Crystal Growth in Candy Making

a. Size of crystals
Boil a sugar and water solution until 114°C. is reached, and then pou
four evaporating dishes. Beat the first portion at once and the othe
to 70°C., 60°C., and 40°C.

Using a low-power magnification of 200x, examine the crystals from ea
size of the crystals varies with the temperature at which they form.

b. Substances controlling crystal size
Prepare the following mixtures in separate beakers:

1. 50 g. cane sugar and 25 ml. H_2O (control)
2. 50 g. cane sugar and 0.1 g. of cream of tartar in 25 ml. H_2O
3. 50 g. cane sugar and 4 ml. of vinegar in 25 ml. H_2O
4. 50 g. cane sugar and 10 ml. of light corn syrup in 25 ml. H_2O
5. 50 g. cane sugar and 25 ml. H_2O and 3 ml. glycerine

Boil each mixture until 115° C. is reached; then pour it into an evaporati
each sample for 2 minutes.

Compare the textures of the mixtures, and discuss measures that can be take
Cookbooks will verify your answers.

To save time, groups of students can be assigned the experiment. Each pup
sponsible for one of the mixtures. Group results can be compared.

Caution pupils about hot boiling syrup and about avoiding seed crystals in

aterials will produce CO_2? Any combination that does produce CO_2 may
baking powder.

cream of tartar, 1 teaspoonful of baking soda, and 1 teaspoonful of
nto two equal portions in 100-ml. beakers. To the first beaker, add 1
well. Now add 10 ml. of water to each beaker, and stir in thoroughly.
of the foam that forms in each case. The proteins from egg and flour
cake from falling.

dy Making

on until 114°C. is reached, and then pour equal portions into each of
t the first portion at once and the other three after they have cooled

on of 200x, examine the crystals from each portion and note how the
ith the temperature at which they form.

l size
s in separate beakers:
l. H_2O (control)
g. of cream of tartar in 25 ml. H_2O
. of vinegar in 25 ml. H_2O
l. of light corn syrup in 25 ml. H_2O
l. H_2O and 3 ml. glycerine

s reached; then pour it into an evaporating dish. Immediately beat

res, and discuss measures that can be taken to insure a soft creamy candy.
rs.

can be assigned the experiment. Each pupil within a group will be re-
. Group results can be compared.

syrup and about avoiding seed crystals in the beaker.

A 5.12 Effect of Bleaches on Fibers

Put a different type of fiber (wool, linen, cotton, silk, nylon, or another
eral test tubes. Cover each fiber with water, and add 5 ml. of chlorine ble
away the bleach and observe the fibers.

Repeat the procedure by substituting hydrogen peroxide or dilute oxalic aci
bleach.

Compare the effects of the bleaches on each fiber.

A 5.13 Effect of Disinfectants on Bacterial Growth

Prepare six sterile, nutrient agar plates.

Keep the first one unexposed for a control.

Expose each of the remaining plates to air for 2 minutes. Then add two dro
solution to each dish. Cover the dishes and let them set for 2-3 days. Dis
are a deodorant soap solution, Lysol, zepherin chloride, chlorine bleach, a
(The use of tap water will prove it is not a disinfectant.)

Observe bacterial growth in each dish daily. Be sure to keep the dishes co
the cultures or endangering pupils with any pathogenic bacteria.

At the conclusion of the experiment, the cultures should be sterilized befo
disposable plastic dishes are used. The plastic dishes and cultures can be

---

(wool, linen, cotton, silk, nylon, or another synthetic fiber) into sev-
iber with water, and add 5 ml. of chlorine bleach. After 5 minutes, rinse
e fibers.

tuting hydrogen peroxide or dilute oxalic acid solution for the chlorine

aches on each fiber.

terial Growth

agar plates.

or a control.

lates to air for 2 minutes. Then add two drops of a different disinfectant
the dishes and let them set for 2-3 days. Disinfectants that might be used
Lysol, zepherin chloride, chlorine bleach, and/or any household cleaner.
ve it is not a disinfectant.)

ch dish daily. Be sure to keep the dishes covered to avoid contaminating
pils with any pathogenic bacteria.

riment, the cultures should be sterilized before discarding the agar unless
used. The plastic dishes and cultures can be burned in the incinerator.

A 6.01 Water Pollution from Oil

Put a drop of thin motor oil on water in a large shallow container such as a c wood or metal across the water. Note the rainbow effect as the thickness of t be necessary to illuminate the surface.)

Repeat the process using water collected from a puddle on a wet street.

A 6.02 Determining the Dissolved Oxygen Content of Water

The determination of dissolved oxygen is one of the most important tests used The following references describe this test in detail: *Standard Methods for t* *Wastewater*, *Laboratory Procedures for Waste Water Treatment for Plant Operator* *and Clearing the Air* (a study unit distributed to schools by the American Petr

The following solutions are required to run the test: 0.1N manganous sulfate per liter); alkali-iodide-azide solution (500 g. of NaOH and 135 g. of NaI. D and dilute to a liter. Then dissolve 1 gram of sodium azide, NaN_3, per 100 ml solution. This gives an alkali-iodide-azide solution which is stable for 2 we solution (dissolve 6.21 g. of $Na_2S_2O_3.5H_2O$ in water and dilute to one liter); (5 grams of starch added to 1 liter of boiling water).

1. Take about 300 ml. of the water to be tested and add 2 ml. of the $MnSO_4$ so alkali-iodide-azide solution. Mix by inverting the bottle for 20 seconds.
2. Allow the $Mn(OH)_2$ precipitate formed to settle, then add 2 ml. of conc. H_2 will be formed in the solution in proportion to the dissolved oxygen origi
3. Measure 200 ml. of the solution from step 2 into an Erlenmeyer flask.
4. Titrate the solution in the Erlenmeyer flask with $N/_{40}$ thiosulfate solutio resulting solution is pale yellow.
5. Add 1 ml. of starch solution to the flask and titrate slowly until the blu disregarding any return of color.

n a large shallow container such as a cookie sheet. Pull a strip of
he rainbow effect as the thickness of the oil film changes. (It may
)

d from a puddle on a wet street.

t of Water

s one of the most important tests used in water pollution control.
test in detail: *Standard Methods for the Examination of Water and*
aste Water Treatment for Plant Operators, and *Conserving our Waters*
ributed to schools by the American Petroleum Institute).

run the test: 0.1N manganous sulfate solution (480g. of $MnSO_4.4H_2O$
n (500 g. of NaOH and 135 g. of NaI. Dissolve separately, combine,
gram of sodium azide, NaN_3, per 100 ml. of the alkali-iodide
azide solution which is stable for 2 weeks); N/40 sodium thiosulfate
H_2O in water and dilute to one liter); conc. H_2SO_4; starch indicator
boiling water).

be tested and add 2 ml. of the $MnSO_4$ solution and 2 ml. of the
by inverting the bottle for 20 seconds.
d to settle, then add 2 ml. of conc. H_2SO_4 and shake. Free iodine
roportion to the dissolved oxygen originally in the water.
n step 2 into an Erlenmeyer flask.
yer flask with $N/_{40}$ thiosulfate solution until the color of the

flask and titrate slowly until the blue color disappears, If exactly N/40 thiosulfate solution is used to titrate 200 ml. of sample, the num thiosulfate used is equivalent to the number of parts per million of dissolved oxy Water at 20°C. holds about 9 p.p.m. of oxygen when saturated.

A 6.03 The 5-day BOD Test on Water

The 5-day BOD (Biochemical Oxygen Demand) test involves making two separate determ oxygen (see A 6.02) on samples taken from the same body of water at the same time. tested immediately, if possible. If this is not feasible, and the initial test mus than 4 hours, the initial sample of water should be refrigerated until tested.

The second sample should be kept in the dark at 20°C. for 5 days before testing it The dissolved oxygen content of the second sample should be lower than that of the difference between the two determinations is the Biochemical Oxygen Demand. If th enough organisms, the oxygen content of the water may drop to 2 mg./l. or even zero it is necessary to add water to some of the original sample and determine the diss mixture as well as that of the pure water used for dilution. The difference betwe the total volume of diluting water and sample, divided by the volume of sample alon original body of water.

A 6.04 Settleable Solids Test

Gently pour a measured quantity (usually 1 liter) of a well-mixed sample of silty w graduated cylinder and allow to stand for a total period of 1 hour. After the samp minutes, gently rotate the graduate between the hands to loosen the solids that ma Allow to settle 15 minutes longer. Read from the graduations the volume of solid m the graduate. Results are expressed as ml. of solids per liter which settled in 1

$$\text{ml. of solids} \times \frac{1000 \text{ ml.}}{\text{ml. of sample}} = \text{ml. of settleable solids per liter.}$$

More accurate results may be obtained if glass cones or stoppered funnels are calib used in place of the graduates. The larger the sample of water, the more accurate t

A 6.05 Testing for the Fluoride Ion

Fluoride ion analyses are modifications of a single colorimetric method which invol preformed color by the fluoride ion. The preformed color comes from the reaction be and either alizarin or SPADNS dyes. The color is formed more slowly with the aliza produced is called a "lake," and the intensity of color fades from red to yellow if t

ion is used to titrate 200 ml. of sample, the number of milliliters of
the number of parts per million of dissolved oxygen in the sample.
n. of oxygen when saturated.

Demand) test involves making two separate determinations for dissolved
ken from the same body of water at the same time. The first sample is
If this is not feasible, and the initial test must be delayed for more
of water should be refrigerated until tested.

in the dark at 20°C. for 5 days before testing it for dissolved oxygen.
he second sample should be lower than that of the first one. The
inations is the Biochemical Oxygen Demand. If the body of water contains
nt of the water may drop to 2 mg./1. or even zero. When this happens,
ome of the original sample and determine the dissolved oxygen of the
re water used for dilution. The difference between these values, times
r and sample, divided by the volume of sample alone, equals the BOD of the

usually 1 liter) of a well-mixed sample of silty water into a large
tand for a total period of 1 hour. After the sample has stood for 45
te between the hands to loosen the solids that may adhere to the sides.
. Read from the graduations the volume of solid material deposited in
sed as ml. of solids per liter which settled in 1 hour.

= ml. of settleable solids per liter.

ined if glass cones or stoppered funnels are calibrated in ml. and
The larger the sample of water, the more accurate the results.

ations of a single colorimetric method which involves the bleaching of a
on. The preformed color comes from the reaction between zirconium ions
s. The color is formed more slowly with the alizarin dye. The color
he intensity of color fades from red to yellow if the concentration of

zirconium ions decreases. Fluoride ions combine with zirconium ions to for
The more fluoride ions present, the greater the change from red to yellow.

The SPADNS test may be made quantitatively by making a set of reference sol
concentrations and reading the absorbences at 570 millimicrons with a spect
described in *Standard Methods for the Examination of Water and Waste Water.*
The qualitative test requires making the following solutions:
SPADNS solution - Dissolve 0.96g. (sodium 2-parasulfophenylazo 1,8 dihydrox
also called Eastman 7309, in de-ionized water and dilute
Zirconyl-acid reagent - Dissolve 0.133 g. zirconyl chloride octahydrate (Zr
de-ionized water. Add 350 ml. of conc. HCl and dilu

The procedure involves mixing equal quantities of SPADNS and zirconyl acid
acid zirconyl-SPADNS reagent. Ten ml.of this reagent is then added to 50 m
A change from a red to a yellow color indicates the presence of the fluorid

A 6.06 Detergents and Algal Growth

Innoculate two sterile water samples with a blue-green algae such as Nostoc
add 1 to 2 ml. of a liquid detergent commonly used for washing dishes. Aft
growth of the algae. A microscopic examination may be necessary if small a
amounts of water have been used.

A 6.07 Effect of Aerating Water

Divide a sample of cold water into two portions. Vigorously beat one sampl
or in a blender. Put both samples of water in stoppered containers, and le
the amount of air bubbles that collect on the container as the water warms
amount of air leaving the water as it warms is a rough comparison of the am
two water samples.

A 6.08 Adsorption With Charcoal

Activate some wood charcoal by gently heating it in an oven or over a low f

From an odiferous fish tank,obtain a 100-200-ml. water sample. To the wate
activated charcoal, and let the mixture stand for several minutes. Note th
charcoal adsorbs the gases.

de ions combine with zirconium ions to form a stable complex ion ZrF_6^{--}.
he greater the change from red to yellow.

itatively by making a set of reference solutions of known fluoride ion
sorbences at 570 millimicrons with a spectrophotometer. The method is
the *Examination of Water and Waste Water.*
ing the following solutions:
(sodium 2-parasulfophenylazo 1,8 dihydroxy-3,6 napthalene disulfonate)
tman 7309, in de-ionized water and dilute to 500 ml.
0.133 g. zirconyl chloride octahydrate ($ZrOCl_2 \cdot 8H_2O$) in about 25 ml. of
d water. Add 350 ml. of conc. HCl and dilute to 500 ml.

al quantities of SPADNS and zirconyl acid reagents to produce a stable
n ml. of this reagent is then added to 50 ml. of the water to be tested.
olor indicates the presence of the fluoride ion.

les with a blue-green algae such as Nostoc or Gleocapsa. In one culture,
ent commonly used for washing dishes. After several days, compare the
ic examination may be necessary if small amounts of culture and large

o two portions. Vigorously beat one sample of water with an egg beater
s of water in stoppered containers, and let them stand overnight. Compare
llect on the container as the water warms to room temperature. The
s it warms is a rough comparison of the amount of dissolved air in the

ntly heating it in an oven or over a low flame.

n a 100-200-ml. water sample. To the water, add a spoonful of the
ixture stand for several minutes. Note the reduction in odor as the

A 6.09 Determining Residual Chlorine by the Iodometric Method

The iodometric method for determining residual chlorine is des
Examination of Water and Waste Water. The method described th
thiosulfate solution followed by a blank determination to corr
or reagents used. Omitting the blank simplifies the procedure
chlorine.

The iodometric method depends upon the fact that chlorine in w
iodide to free iodine if the pH is less than 8.0. The release
and this solution is titrated quantitatively with thiosulfate
determine the end point. The temperature of the water sample
If the water being tested has a pH of 6.0 to 8.0, the minimum
will range from 1.0 to 1.8 mg./1. The concentration of free c
determined from the following equation: mg./liter Cl = (A) X
thiosulfate used in the titration,and N is the normality of th

The procedure is as follows: Dissolve 25g. of $Na_2S_2O_3 \cdot 5H_2O$ in
thiosulfate solution. Add 5 ml. of acetic acid and about 1 g.
tested. Stir until the KI is dissolved, and then titrate the
until the yellow color of the liberated iodine becomes pale. T
slowly until the blue color disappears.

When orthotoluidine is added to water, a characteristic yellow
This color, when used with standard solutions, gives a quantit
Some ions interfere with this simple test which takes little t
companies which sell equipment for swimming pools.

A 6.10 Effect of Air Pollution on Nylon

Cut a 4-inch x 4-inch opening in two pieces of cardboard. Str
opening in one cardboard and glue the other cardboard on top o
Support the mount so that the nylon is held in a horizontal po
nylon in an unobstructed and safe place such as on the school
another for 90 days. A sample stored inside for the same peri

At the end of its exposure period, examine each sample for brok
microscope, or magnifying glass). Record the number of breaks

Iodometric Method

residual chlorine is described in Standard Methods for the
The method described there calls for a titration with a standard
ank determination to correct for interfering substances in the water
simplifies the procedure and gives an approximate value for residual

e fact that chlorine in water will oxidize iodide ions from potassium
ss than 8.0. The released iodine imparts a yellow color to the water,
atively with thiosulfate solution. A starch indicator is used to
ture of the water sample used should be as close to 20°C. as possible.
6.0 to 8.0, the minimum quantity of total available residual chlorine
e concentration of free chlorine in the water being tested can be
n: mg./liter Cl = $\frac{(A) \times N \times 35,450}{\text{ml. sample}}$, where A is the number of ml. of
N is the normality of the thiosulfate solution.

e 25g. of $Na_2S_2O_3 \cdot 5H_2O$ in de-ionized water to make a liter of 0.1N
cetic acid and about 1 g. of KI to a 500-ml. sample of the water to be
ed, and then titrate the sample with the standard thiosulfate solution
ed iodine becomes pale. Then add 1 ml. of starch solution and titrate
s.

, a characteristic yellow color is produced by chlorine in the water.
olutions, gives a quantitative measure of the chlorine concentration.
test which takes little time. Kits are available for this test from
imming pools.

pieces of cardboard. Stretch a square piece of nylon hose over the
e other cardboard on top of it so as to form a slide mount of the nylon.
is held in a horizontal position between two wooden blocks. Expose the
ace such as on the school roof. Expose one sample for 30 days, and
d inside for the same period may be used as a control for comparison.

amine each sample for broken threads (use a slide projector, low-power
ecord the number of breaks per day of exposure for each sample.

The known probable destructive agents of nylon hose are hot partic
furic acid, acid aerosols, nitrogen oxides, phenolic particulates,
engines, and solvent vapors and droplets.

A 6.11 Characteristics of a Smoke

Place a few drops of concentrated hydrochloric acid in a small dis
few drops of concentrated ammonia. DO NOT MIX THESE CHEMICALS! T
will react to form a cloud of white, solid ammonium chloride.

A 6.12 Dust Pollution

Very small particles can often be seen by a very bright reflected
invisible in ordinary light. Have pupils observe the motes (small
as it passes into a darkened corner of the room. Ordinarily, one
these small particles.

A 6.13 Investigating the Cleanliness of Air

Polluted air may contain many more suspended solids than clean air
be seen when filtered from the air. Air samplers run by State and
of air through fiber glass filters, and the particles trapped in t
determine their identity.

A simple air sampler can be made that will show the relative clean
localities. If there is an old vacuum cleaner available, fasten a
tape a piece of filter paper by the edges over the screen so that
Place the vacuum cleaner in a suitable location, and let it run for
filter paper.

Light transmittance or reflectance may be used to measure the dark
tometer can be made by using a light meter or solar cell hooked up
the light reflected from the surface of the paper. Obtain a readi
a piece of clean filter paper used as a control to provide a basis

If a sensitive balance is available, the mass of the trapped parti
paper before and after exposure. The paper may also be rinsed in
the resulting solution determined.

ents of nylon hose are hot particles contained in smoke, soot with sul-
en oxides, phenolic particulates, aldehydes from internal combustion
roplets.

hydrochloric acid in a small dish. Close by, place a dish containing a
. DO NOT MIX THESE CHEMICALS! The gaseous vapors of these two substances
te, solid ammonium chloride.

seen by a very bright reflected light even though they are practically
e pupils observe the motes (small dust particles) in a beam of sunlight
er of the room. Ordinarily, one would not be aware of the existence of

Air

e suspended solids than clean air. Much of this material is dark and can
r. Air samplers run by State and Federal agencies draw measured amounts
s, and the particles trapped in the filters are collected and analyzed to

that will show the relative cleanliness of air samples from different
acuum cleaner available, fasten a wire screen to the end of the hose and
he edges over the screen so that air can be drawn through the filter paper.
table location, and let it run for several hours drawing air through the

e may be used to measure the darkening of the surface. A simple reflec-
ght meter or solar cell hooked up in series to a microammeter to measure
ace of the paper. Obtain a reading from the exposed paper and also from
d as a control to provide a basis for comparison.

le, the mass of the trapped particles may be found by weighing the filter
The paper may also be rinsed in a measured quantity of water, and the pH of
.

A 6.14 Collection of Wind-Blown Particles

Wind-blown particles may be collected on the surface of a sticky paper wrappe
hung in a vertical plane in a suitable location. The paper may be prepared l
supplier (Fasson Products Division of Avery Paper Company, 250 Chester Street
3-inch diameter piece of wood dowel is fastened to a suitable base, and the j
is fastened to the top of the dowel so that the jar in an upside-down positio
top. If the jar used is 2 3/4 inches in diameter, the size of the collecting

The sticky paper is wrapped around the jar, the jar mounted on the dowel, and
where the wind will have a clean sweep. Mark the paper where it faces north
days. After exposure, spray the paper with a clear lacquer and compare the s
photographic standard for particles per square inch (obtainable from Technica
P. O. Box 116, Park Ridge, New Jersey 07656).

A 6.15 Measuring the Amount of Dustfall

Add 1 quart of distilled water into a clean wide-mouth glass jar (1-gallon si
the top to keep insects out. Place the jar outdoors in an exposed place, 5 f
tilled water from time to time to keep the water level up to 1 quart. Rain c
less the jar overflows; if it does, start again. Freezing should be avoided
cracking.

At the end of a 30-day exposure, transfer all the liquid in the jar, a little
ing dish of known mass, and heat carefully to avoid spattering. Scrape the s
flush with a stream of water. This wash water should also be added to the ev

Evaporate all the water and weigh the dish and its contents. Calculate by su
dust. Find the area of the jar opening (assume that the opening is a circle
the dust in terms of milligrams per square centimeter of exposed area for 30
other than 30 days is used, make the necessary adjustment. Measurements of d
in tons per square mile for 30 days. Use the factor-label (multiplying by un
results to these units.

A 6.16 Liquid Pollutants

Use a perfume atomizer or an aerosol can of air freshener to spray a mist int
in a window. Observe the tiny droplets of moisture. Caution! Do not use an
that no open flames are in the room during the spraying or for several minute

ted on the surface of a sticky paper wrapped around a small jar which is able location. The paper may be prepared locally or purchased from a of Avery Paper Company, 250 Chester Street, Painesville, Ohio). A l is fastened to a suitable base, and the jar top of the jar to be used l so that the jar in an upside-down position can be screwed to the jar hes in diameter, the size of the collecting strip can be 2 x 10 inches.

the jar, the jar mounted on the dowel, and the whole apparatus is put weep. Mark the paper where it faces north and leave it exposed for 7 paper with a clear lacquer and compare the surface of the paper with a s per square inch (obtainable from Technical Associates for Industry, Inc., sey 07656).

o a clean wide-mouth glass jar (1-gallon size). Place a wire screen over e the jar outdoors in an exposed place, 5 feet off the ground. Add dis- keep the water level up to 1 quart. Rain or snow causes no trouble un- , start again. Freezing should be avoided to prevent the jar from

ransfer all the liquid in the jar, a little at a time, into an evaporat- arefully to avoid spattering. Scrape the sides of the jar clean, and s wash water should also be added to the evaporating dish.

the dish and its contents. Calculate by subtraction the weight of the pening (assume that the opening is a circle with an area πr^2). Calculate r square centimeter of exposed area for 30 days. If a time interval he necessary adjustment. Measurements of dustfall are commonly expressed s. Use the factor-label (multiplying by unity) method and change your

sol can of air freshener to spray a mist into a beam of sunlight coming plets of moisture. Caution! Do not use an insecticide bomb. Make sure m during the spraying or for several minutes thereafter.

A 6.17 Effect of Oil Pollutants on Plants

Certain particulate pollutants may clog the stomata, or openings, on
fere with the passage of water vapor and other gases in and out of th
a few leaves of a geranium plant can be used to demonstrate this. Va
lutant, may be used more effectively to demonstrate the clogging of le
leaves on a healthy green plant. Coat them with vaseline, making sure
Observe the condition of these leaves as compared with the uncoated le
of time. An interesting variation of this experiment would involve co
only, one leaf on the top surface only, and one leaf on both sides. W
the results of the experiment?

A 6.18 Sulfur Dioxide in Air

Cut a 10-inch length of 6-mm. soft glass tubing. Using a Bunsen flame
until an opening 0.008 - 0.01 inches is attained. Make a right-angle
inches from the open end. Insert the tube through a one-hole stopper
taining 10 ml. of distilled water. Using an appropriate pump attached
water for at least 10 minutes. Transfer the water through which the ai
flask. If SO_2 was present in the air sample, the flask will contain 1
centration is unknown.

Titrate into the Erlenmeyer flask a 0.01M potassium permanganate soluti
added to the sulfurous acid solution slowly, drop by drop, and with co
approaches, a transistory faint brown color may appear. The end point
in the solution in the flask which does not disappear upon stirring. F
sulfurous acid react with 2 moles of permanganate, the concentration of
lated.

The total number of moles of SO_2 dissolved in the 10 ml. of water = ml.

A 6.19 Total Acids in Air

Connect the stem of a thistle tube to an air pump or aspirator. Over th
tube, attach a piece of wet strength white paper towel by an elastic ban
ruptures when wet after the pump is turned on, use a piece of wire scree

lants

s may clog the stomata, or openings, on the leaves of green plants and inter-
r vapor and other gases in and out of the leaf. Moderately heavy dusting of
ant can be used to demonstrate this. Vaseline, though not a particulate pol-
ctively to demonstrate the clogging of leaf "pores." Select two or three
nt. Coat them with vaseline, making sure that all surfaces are covered.
e leaves as compared with the uncoated leaves on the same plant over a period
ation of this experiment would involve coating one leaf on the bottom surface
face only, and one leaf on both sides. What conclusions can be drawn from
?

soft glass tubing. Using a Bunsen flame, almost close one end of the tubing
inches is attained. Make a right-angle bend in the tubing about 2 or 3
sert the tube through a one-hole stopper that fits a side-arm test tube con-
ater. Using an appropriate pump attached to the side-arm, draw air into the
. Transfer the water through which the air has passed to a 250-ml. Erlenmeyer
the air sample, the flask will contain 10 ml. of sulfurous acid whose con-

lask a 0.01M potassium permanganate solution. The $KMnO_4$ solution should be
olution slowly, drop by drop, and with continual stirring. As the end point
nt brown color may appear. The end point is reached when a pink color forms
which does not disappear upon stirring. From the fact that 5 moles of
oles of permanganate, the concentration of the sulfurous acid may be calcu-

$$SO_2 \text{ dissolved in the 10 ml. of water} = \text{ml. of } KMnO_4 \times \frac{5 \times 10^{-5}}{2}$$

tube to an air pump or aspirator. Over the open bulb end of the thistle
trength white paper towel by an elastic band. If it is found that the paper
ump is turned on, use a piece of wire screen to support the paper.

Add one drop of 0.1 percent indicator (1 g. of methyl orange dissolved in
of 0.01 sodium bicarbonate buffer (0.94 g./liter) to the paper. More drop
a yellow color is not apparent. Add, also, a drop of glycerin to keep the

When the air pump is started, the acids in the air passing through the pap
to drop, and the color of the indicator will change from yellow to red. W
has little effect on the indicator, but SO_2 and other compounds in the air
will cause the color to change.

For a preliminary test, draw air from an open bottle of dilute HCl. Use a
for the color change from yellow to red. Repeat with samples of air from
of time needed for the color change is a measure of the relative acidity o

A 6.20 Construction of an Electrostatic Precipitator

A description of the construction of an electrostatic precipitator from a
induction coil, 6-volt battery, and knife switch is given in *Conserving Our*
a student manual produced by the American Petroleum Institute and distribu
book, giving essentially the same information, is *Scientific Experiments in*
published by Holt, Rinehart and Winston.

A 6.21 Afterburners

Place a clean cold dish in a candle flame. The soot formed is a result of
candle fuel. Heating this soot in a hot Bunsen flame causes it to disappe
kind of pollution control might be suggested by this demonstration?

A 6.22 Biodegradability of Solids

Prepare 1-inch x 3-inch strips of various solids: paper (colored toilet ti
facial tissue, paper towel, paper bag, typing paper, label paper from a ti
(aluminum foil, pieces of metal containers), and plastic (saran, polyethyl
candy wrappings, etc.). Measure the average thickness of each strip with a
thin to measure accurately, measure the combined thickness of ten sheets a
meter reading.

Bury each sample vertically in a deep pan containing garden soil or compos
remains above the soil level. Numbers placed on the projecting ends will
the soil moist by watering it every day.

icator (1 g. of methyl orange dissolved in one liter of water) and one drop
er (0.94 g./liter) to the paper. More drops of indicator may be needed if
Add, also, a drop of glycerin to keep the paper from drying out.

he acids in the air passing through the paper will cause the pH in the paper
ndicator will change from yellow to red. With the buffer present, CO_2
tor, but SO_2 and other compounds in the air which produce stronger acids

r from an open bottle of dilute HCl. Use a timer to find the elapsed time
w to red. Repeat with samples of air from various locations. The length
ange is a measure of the relative acidity of the air sample.

c Precipitator

on of an electrostatic precipitator from a cardboard tube, aluminum foil,
and knife switch is given in Conserving Our Waters and Clearing the Air,
e American Petroleum Institute and distributed free to schools. Another
e information, is Scientific Experiments in Pollution Control, which is
Winston.

ndle flame. The soot formed is a result of incomplete combustion of the
in a hot Bunsen flame causes it to disappear. Why? What ideas for one
be suggested by this demonstration?

of various solids: paper (colored toilet tissue, white toilet tissue,
er bag, typing paper, label paper from a tin can, cardboard, etc.), metal
containers), and plastic (saran, polyethylene, cellophane, cigarette, and
the average thickness of each strip with a micrometer. If a sheet is too
sure the combined thickness of ten sheets and take one-tenth of the micro-

a deep pan containing garden soil or compost so that only about 1 inch
Numbers placed on the projecting ends will help in identification. Keep
very day.

If four duplicate samples of each solid are used, a sample may be remove
vations include the thickness and appearance (extent of decay) of each sa
samples from the most biodegradable to the least biodegradable.

A 6.23 Some Problems of Incineration

Prepare samples (about 4cm.^{2}) of paper, plastic materials, food wraps, fab
with labels, newspapers, etc. Place a sample on a wire gauze which is ce
lighted burner beneath the sample and note the time. Observe the sample
note the time again. If smoke is emitted, find out whether or not a sec

A tabulated record should be kept for each sample. The data collected ma
after heating, the elapsed time of heating, evidences of steam, color, ar
tics of the residue, and other observations such as: burns with a flame,
flows, burns like paper.

Distinguish between burning (addition of oxygen) and pyrolysis (decomposi
flame alone). Ask students to evaluate to what degree the sample shows t
incineration.

Throughout the activity, try to keep the quality and height of the flame c
nate these variables.

A 6.24 Finding the Scrap Value of an Aluminum Can

Have each class member bring in one used 12-oz. beverage can. Use magne
the aluminum cans. Weigh each aluminum can, and find the average mass pe

Find the number of aluminum cans there would be in a ton. Use the follo

$$\frac{2 \times 10^3 \text{ lb.} \times 4.54 \times 10^2 \text{ g./lb.}}{\text{g./can}}$$

Local scrap yards should know the current value for a ton of aluminum sc
the price per ton (in cents) by the number of cans per ton, will give th
minum can.

f each solid are used, a sample may be removed each week for 1 month. Obser-
ss and appearance (extent of decay) of each sample. Prepare a list of the
gradable to the least biodegradable.

on

) of paper, plastic materials, food wraps, fabrics, cardboard, foil, tin cans
c. Place a sample on a wire gauze which is centered on a tripod. Place a
sample and note the time. Observe the sample until no more changes occur and
oke is emitted, find out whether or not a second flame will burn the smoke.

e kept for each sample. The data collected may include the mass before and
time of heating, evidences of steam, color, and density of smoke, characteris-
her observations such as: burns with a flame, burns with a glow, melts and

(addition of oxygen) and pyrolysis (decomposition caused by the heat of the
to evaluate to what degree the sample shows that it can be disposed of by

to keep the quality and height of the flame constant for each sample to elimi-

an Aluminum Can

g in one used 12-oz. beverage can. Use magnets to separate any steel cans from
ach aluminum can, and find the average mass per can.

cans there would be in a ton. Use the following relationship:

/lb.

ow the current value for a ton of aluminum scrap (about $200/ton). Dividing
) by the number of cans per ton, will give the scrap value in cents of an alu-

A 7.01 Exhibiting Polymers

Display some polymers such as glass, modeling clay, amber, hair, shellac, gum, res
spray, nail polish, paper, wood, meat, wool, silk, and plastics. Ask the pupils t
can be classified into the same category.

Point out that the items can be subdivided into natural polymer and manmade polym

A 7.02 Obtaining Casein from Milk

Add rennet (Junket tablet) to a pint of milk (35 - 40°C.) to form curds which co
the milk has "set," filter by suction, and wash the curds. (Use decantation if th
be separated by a filter.) The dried curds are casein.

When soaked in water, casein powder can form a soft, pliable plastic which can be

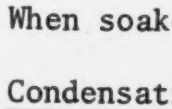
A 7.03 Condensation Polymerization

Have a team of pupils build models of two phenol molecules and one formaldehyde mo
to join the molecules by following the condensation rules - no more than 1 H or 1
from any molecule and no more than a total of 2 H and 1 O can be removed to form H

The condensation products of all the teams can be joined together. If on a single
are used, a network can be built up and the rigid structure of a "set" polymer sho

A 7.04 Addition Polymerization

Ball-and-stick models can be used to illustrate the joining of monomers to form lo

Have each pupil (or team) make ball-and-stick models for several molecules of acry

$CH_2 = CH(CN)$. Ask the pupils to join their monomers to form one unit, then have pupil
to make Orlon. Point out that inhibitor chemicals are used to determine the lengt
desired. Hydrogen may be added to complete the final molecule's bonding.

ng clay, amber, hair, shellac, gum, resin, laundry starch, hair , silk, and plastics. Ask the pupils to "guess why" the items

into natural polymer and manmade polymer groups.

ilk (35 - 40°C.) to form curds which contain the casein. When wash the curds. (Use decantation if the curds are too small to are casein.

m a soft, pliable plastic which can be molded.

henol molecules and one formaldehyde molecule. Tell the pupils ensation rules - no more than 1 H or 1 O atom can be removed of 2 H and 1 O can be removed to form H_2O.

can be joined together. If on a single phenol all linkage sets rigid structure of a "set" polymer shown.

rate the joining of monomers to form long chain polymers.

ck models for several molecules of acrylonitrile monomer, omers to form one unit, then have pupils join their "units"

emicals are used to determine the length of polymer chains the final molecule's bonding.

A polyethylene model can be made in a similar manner from C_2H_4

A 7.05 Preparation of a Plastic Similar to Bakelite

Teacher Demonstration

Simultaneously pour 100 ml. of a saturated solution of aniline
formalin solution into a 300-ml. beaker. Stir with a glass rod
mold. When hardened, the black substance is a plastic similar

A 7.06 Identification of Vinyl Chloride Polymers

Weigh out equal masses of Saran (a vinyl chloride polymer) and
bags are made of polyethylene. Mount an inverted funnel on a r
from the stem of the funnel into a beaker containing 100 ml. of
the funnel so that the smoke is collected and dissolved in the
peat the procedure using polyethylene and a new sample of water.
contains HCl which produces a lower pH in water than the smoke

Test different plastic food wraps, containers, and phonograph r
chloride polymers. Point out that some plastics have similar p
structures.

A 7.07 Testing Fibers

Obtain some samples of cotton, linen, wool, silk, nylon, Orlon,
or Spandex. Most fabrics purchased at the local store are blend
samples be obtained from a mill or chemical company.

Inspect shredded fibers of each type of material under the low p

Test the combustibility, resistance to 3N HCl, chlorine bleaches
and tensile strength of each fiber. Relate the results to any s

A 7.08 Thermoplastics

The properties of a thermoplastic material can be illustrated wi ade in a similar manner from C_2H_4 monomer units.

lar to Bakelite

of a saturated solution of aniline hydrochloride and 100 ml. of 40-percent -ml. beaker. Stir with a glass rod. Pour the viscous materials into a sand ack substance is a plastic similar to Bakelite.

ride Polymers

ran (a vinyl chloride polymer) and polyethylene. Most plastic sandwich e. Mount an inverted funnel on a ringstand, and connect a piece of tubing into a beaker containing 100 ml. of distilled water. Burn the Saran under is collected and dissolved in the water. Test the pH of the water. Re- yethylene and a new sample of water. The smoke from vinyl chloride polymers a lower pH in water than the smoke from nonchloride containing polymers.

wraps, containers, and phonograph records to determine if they are vinyl t that some plastics have similar properties and appearances but different

n, linen, wool, silk, nylon, Orlon, Rayon, and an elastic yarn, such as Lycra rchased at the local store are blends of fibers. It is suggested that pure ill or chemical company.

ach type of material under the low power of a microscope.

sistance to 3N HCl, chlorine bleaches, 1 N NaOH, retention of water, elasticity, fiber. Relate the results to any specific uses of the fiber.

lastic material can be illustrated with sealing wax, a natural resin plastic.

In its normal state, sealing wax is a hard solid. When warmed over a m
the pull of gravity. When a blob of molten sealing wax is stamped with
the shape of the imprint. As it cools, the wax resets to a plastic and
impressed upon the wax.

A 7.09 Cold-Setting Plastic

Cold-setting plastic can be illustrated by using the "bioplastic" mater
ing specimens. The plastic syrup and catalyst can be purchased from mo

A 7.10 Identification of Thermosetting and Thermoplastic Materials

Classify a number of plastic materials as thermoplastic or not thermopl
plastic in boiling water for several minutes. Those that can be bent o
thermoplastics. Include samples of Bakelite, polystyrene, synthetic ru
plastic "wrap" or bags, and a toothbrush handle. The temperature of bo
to identify all thermosets from thermoplastics.

A 7.11 Properties of Plastics

Obtain many samples of plastics used in the home. Some examples are sq
old toothbrushes, wrapping products, nylon, yarn, and a broken electric

Classify each according to transparency, color, flammability, hardness,
water, alcohol, nail polish remover, sodium hydroxide, hydrochloric aci

Relate the uses of the material to any properties observed.

A 7.12 Use of the Geiger Counter

Many schools have rate meters or scalers of the Geiger counter type. T
difference between alpha, beta, and gamma emission in terms of the rang
the ability of varying thicknesses of different materials to absorb the
gamma emitters are available commercially in sealed plastic containers
students. The Geiger tube is not 100 percent efficient in registering
particularly poor for counting gammas. Section 6.05 of the Chemistry H
the use of the Geiger counter and factors which affect count rates.

ing wax is a hard solid. When warmed over a match, it will melt and flow under
n a blob of molten sealing wax is stamped with a "seal," the wax flows and takes
As it cools, the wax resets to a plastic and the pattern of the stamp remains

be illustrated by using the "bioplastic" materials that biologists use in mount-
ic syrup and catalyst can be purchased from most scientific supply houses.

etting and Thermoplastic Materials

tic materials as thermoplastic or not thermoplastic by immersing the pieces of
for several minutes. Those that can be bent or are softened by the heat are
samples of Bakelite, polystyrene, synthetic rubber, sealing wax, polyethylene,
nd a toothbrush handle. The temperature of boiling water is too low to be used
s from thermoplastics.

astics used in the home. Some examples are squeeze bottles, toys, old jewelry,
g products, nylon, yarn, and a broken electric plug.

o transparency, color, flammability, hardness, elasticity, and solubility in
sh remover, sodium hydroxide, hydrochloric acid, and sulfuric acid.

terial to any properties observed.

r

eters or scalers of the Geiger counter type. These can be used to show the
, beta, and gamma emission in terms of the range of these radiations in air and
hicknesses of different materials to absorb these radiations. Alpha, beta, and
able commercially in sealed plastic containers which can be handled safely by
be is not 100 percent efficient in registering emissions it receives. It is
unting gammas. Section 6.05 of the Chemistry Handbook has a good discussion of
unter and factors which affect count rates.

A 7.13 Counting Geometry

If your school has a Geiger counter with a thin end window, you can show that sharply as the source is moved away from the end window just a few centimeter the source does not actually touch the window at the beginning. Thin end win and tubes containing them are expensive.

A 7.14 The Absorption of Carbon Dioxide by Plants

Seal the pot and soil surface of a geranium with aluminum foil, and place the or beaker. With a wire, support a small beaker within 2 inches of the top of beaker place .5g. of dry $BaCO_3$ which has previously been mixed with 10 microc carbon 14. This can be done by making a paste of the nonradioactive $BaCO_3$ an Allow the mixture to dry in air.

Cover the plant, jar, and beaker with Saran wrap. This should be "airtight." directly over the $BaCO_3$ container, attach two pieces of cellophane tape crosse a pipette through the taped area and inject about 2 ml. of vinegar or dilute The reaction results in CO_2 being released, and part of it is $C^{14}O_2$. Seal the Place the entire setup in a fume hood under a strong light for 24 hours. The an end window tube, count both the upper and lower surfaces of leaves cut fro

Dispose of any excess $BaC^{14}O_3$ by flushing it down the drain with a large quan

A 7.15 The Minimum Activity of a Radioisotope Required for Detection

Prepare six 100-ml. solutions of P^{32}. These solutions should have a strength 2.0μc., 3.0μc., and 3.2μc. The total strength of all six solutions must not all combined. Adjust the pH of the solutions so they are brought to just a r

Remove six 5-week-old bean plants from a culture solution in which they have and place one in each of the six solutions.

Counts should be made frequently when the experiment is started to indicate t in the plants; intervals of 15-20, 30-40, 60-75 minutes might be chosen. Tak counter from the radioactive solution while counting leaves. (Folded Al foil radiation.) Care should be taken to duplicate the counting geometry as accura counting of successive leaves. Thereafter, further readings after 6-8 hours a

er counter with a thin end window, you can show that the count rate drops very
moved away from the end window just a few centimeters. Be careful that
lly touch the window at the beginning. Thin end windows are very fragile,
are expensive.

Dioxide by Plants

face of a geranium with aluminum foil, and place the sealed pot in a glass jar
support a small beaker within 2 inches of the top of the jar. Into the small
$BaCO_3$ which has previously been mixed with 10 microcuries of $BaCO_3$ containing
one by making a paste of the nonradioactive $BaCO_3$ and mixing with it the $BaC^{14}O_3$.
in air.

beaker with Saran wrap. This should be "airtight." On the wrap at a point
ontainer, attach two pieces of cellophane tape crossed at right angles. Insert
ed area and inject about 2 ml. of vinegar or dilute HCl into the beaker of $BaCO_3$.
O_2 being released, and part of it is $C^{14}O_2$. Seal the puncture hole with tape.
a fume hood under a strong light for 24 hours. Then open the wrapping and with
both the upper and lower surfaces of leaves cut from the plant.

$^{14}O_3$ by flushing it down the drain with a large quantity of water.

Radioisotope Required for Detection

ions of P^{32}. These solutions should have a strength of 0.3μc., 0.5μc., 1.0μc.,
. The total strength of all six solutions must not exceed 10μc., if they were
pH of the solutions so they are brought to just a red reaction on litmus.

plants from a culture solution in which they have been growing, rinse them off,
the six solutions.

quently when the experiment is started to indicate the first appearance of P^{32}
of 15-20, 30-40, 60-75 minutes might be chosen. Take great care to shield the
ve solution while counting leaves. (Folded Al foil should absorb all beta
e taken to duplicate the counting geometry as accurately as possible with the
aves. Thereafter, further readings after 6-8 hours and 24 hours would be useful

in determining the maximum uptake. Before and after each set of readings, re This will be useful in establishing the minimum amount of P^{32} detectable. Th subtracted from each leaf count in order to find the radioactive count due to

A 7.16 Simulating the Use of a Radioisotope for Diagnosis

A mailing tube or other paper cylinder can be partly filled with sand or loos gamma source hidden in the tube. Pupils could be told that the tube represen given a radioisotope for diagnosis. Use the Geiger counter to locate the sou emits.

A 7.17 Measuring a Liquid Level by Using a Radioisotope

Radioisotopes have been used to indicate the varying height of liquids stored This can be demonstrated by taping a sealed gamma emitter inside an evaporati inside an aquarium or battery jar containing a small amount of water. As mor jar, the evaporating dish containing the sealed source moves up in the jar an ed with a Geiger counter. A sheet of black construction paper can be used to the counter from seeing the location of the evaporating dish.

A 7.18 Using a Radioisotope to Gauge Thickness

The use of a radioisotope thickness gauge can be demonstrated fairly easily w sealed source of gamma radiation. Place the counter on a table or desk top. near enough to the counter to make the counter register its maximum rate. Th cardboard between the source and probe. The counter should show a slightly l slide a couple of books of different thickness one at a time through the spac count rates. Try an empty beaker and then several filled with different liqu thin sheets of various metals and combine some of the sheets to get varying t The gamma radiation can be concentrated into more of a beam if the source is can.

A 7.19 Half-life Measurement

Half-life measurements can be made using beta and gamma sources which have sh "geometry" must be the same for all counts made with the counter. Iodine-131 8.08 days, and phosphorus-32, with a half-life of 14.3 days, have been used. Th efore and after each set of readings, record the background count. he minimum amount of P^{32} detectable. The background count must be der to find the radioactive count due to P^{32}.

for Diagnosis

r can be partly filled with sand or loosely folded paper and a sealed ils could be told that the tube represents a person who has been Use the Geiger counter to locate the source from the radiation it

adioisotope

ate the varying height of liquids stored in large tanks. sealed gamma emitter inside an evaporating dish and floating the dish taining a small amount of water. As more water is poured into the the sealed source moves up in the jar and its movement can be detect- black construction paper can be used to keep the person operating of the evaporating dish.

ss

auge can be demonstrated fairly easily with a Geiger counter and a ace the counter on a table or desk top. Put the gamma source just e counter register its maximum rate. Then pass a piece of e. The counter should show a slightly lower count rate. Next, thickness one at a time through the space and note the resulting then several filled with different liquids, including water. Try bine some of the sheets to get varying thicknesses of the metals. ed into more of a beam if the source is enclosed in a metal tube or

ing beta and gamma sources which have short half-lives. The counting ounts made with the counter. Iodine-131, which has a half-life of lf-life of 14.3 days, have been used. There are companies which sell

"generators" of barium-137, which has a half-life of only 2.6 minutes. A
against the count rate, and when the counting rate is less than half the
be read directly from the graph as the length of time necessary for the
its initial rate.

A 7.20 Effects of Radioactivity on Living Plants

Many science supply houses sell seeds which have been irradiated. These
hour in a chlorine bleach solution   (1 part bleach to 8 parts water) to
and grow the seeds in moist blotter paper or paper toweling. One techni
blotting paper, then put it into a beaker containing a little water so th
inside the glass. The seeds are placed between the paper and the glass

Use nonirradiated seeds as a control, and note the differences between th
plants with regard to root length, stem length, number of roots, leaf siz

A 7.21 Looking for Radioactive Fallout in Rain and Snow

Collect about 500 ml. of rainwater or melted snow. Evaporate the sample,
from an infrared lamp, until only about 2 ml. remain. Take several backg
background level of radiation. Repeat the procedure, this time keeping t
than 5 centimeters from the concentrated sample. (Because of the reducti
weapons in the atmosphere, this activity may not show any appreciable rad

A 7.22 Using a Radioisotope To Determine the Efficiency of a Cleanser

One of the problems involved in using radioisotopes is that of decontamin
spilled. As far as possible, the same procedures are used with radioisot
material. Spills involving low levels of radiation are mopped up using a
the mopping efficiency. Solutions of various soaps and detergents will v
up the radioisotopes.

This can be shown if equal small quantities of a short-lived radioisotope
beakers, each containing 10 milliliters of water. The activity of each so
proceeding. Once the activity of each solution is known and recorded, it
of a waxed floor tile, which is available in many schools. A small quanti
on the spill and rubbed in with a wooden splint. Equal quantities of soa
out beforehand. Each tile should then be wiped dry with paper towels. Ca
any of the spill on the hands, and the used towels should be put into a pla

137, which has a half-life of only 2.6 minutes. A graph is made by plotting time
and when the counting rate is less than half the initial rate, the half-life can
e graph as the length of time necessary for the activity to drop to one-half of

on Living Plants

es sell seeds which have been irradiated. These seeds can be soaked for half an
h solution (1 part bleach to 8 parts water) to inhibit fungus growth. Germinate
ist blotter paper or paper toweling. One technique is to make a cylinder of the
it into a beaker containing a little water so that the paper cylinder is just
eeds are placed between the paper and the glass wall of the beaker.

as a control, and note the differences between the control plants and experimental
ot length, stem length, number of roots, leaf size, and rate of germination.

Fallout in Rain and Snow

rainwater or melted snow. Evaporate the sample, using either no heat or the heat
ntil only about 2 ml. remain. Take several background counts and get an average
ation. Repeat the procedure, this time keeping the counting tube window no more
he concentrated sample. (Because of the reduction in the testing of nuclear
e, this activity may not show any appreciable radiation levels above background.)

Determine the Efficiency of a Cleanser

lved in using radioisotopes is that of decontamination if a radioisotope is
ible, the same procedures are used with radioisotopes as with any other hazardous
ng low levels of radiation are mopped up using a soap or detergent to increase
Solutions of various soaps and detergents will vary in their abilities to pick

l small quantities of a short-lived radioisotope are measured into several small
0 milliliters of water. The activity of each solution should be checked before
ivity of each solution is known and recorded, it can be spilled upon the surface
ch is available in many schools. A small quantity of soap can be put directly
n with a wooden splint. Equal quantities of soap or detergent should be weighed
e should then be wiped dry with paper towels. Care should be taken not to get
ands, and the used towels should be put into a plastic bag for disposal.

After each tile has been wiped dry, the Geiger counter probe should
and each tile should be placed near the window of the probe for coun
probe and tile should be kept the same for each tile. The tile whic
rate decrease should be that for which the soap or detergent was mos

It is important that the radioisotope used be one with a fairly short
radioactivity on both tile and paper towels will decrease quickly. N
longer than the 8 days of iodine-131 should be used for this activity
generator is an ideal source of radiation. The parent tin-113 has a
indium-113 daughter,which is eluted from the parent,has a half-life o
generator is commercially available.

A 8.01 Identification of a Precipitate

Before class, prepare solutions of $BaCl_2$ and K_2SO_4 (1 g./100 ml.). L
B," respectively.

Have the pupils mix equal quantities of "A" and "B," and try to identi
of solubility charts and properties of substances listed in handbooks

Draw the pupils attention to the large number of possible compounds t
solubility and inability to precipitate easily.

A 8.02 Separation of Two Precipitated Ions

Prepare (2 g./100 ml.) solutions of Na_2CrO_4, $Pb(NO_3)_2$, $NaNO_3$, $Mg(NO_3)_2$
Ask the pupils to find which metallic ions can be precipitated as chl
precipitates are soluble in hot water, which in concentrated ammonium
are affected by light.

Give pupils a solution containing both Pb^{++} and Ag^{+} ions, and ask them
a confirming test for each.

A 8.03 Identification of Halides by Precipitation

Compare the effect of silver nitrate solution on halogen ions. Repeat
solutions. Observe the behavior of the silver and lead halides in sun
in hot water and dilute HNO_3.

wiped dry, the Geiger counter probe should be mounted in a stationary position
placed near the window of the probe for counting. The counting distance between
kept the same for each tile. The tile which shows the greatest percentage count
that for which the soap or detergent was most efficient.

radioisotope used be one with a fairly short half-life, so that the level of
le and paper towels will decrease quickly. No radioisotope having a half-life
f iodine-131 should be used for this activity. A tin-113/indium-113 isotope
urce of radiation. The parent tin-113 has a half-life of 115 days, and the
h is eluted from the parent,has a half-life of only 100 minutes. This isotope
y available.

---

ipitate

lutions of $BaCl_2$ and K_2SO_4 (1 g./100 ml.). Label them "Solution A" and "Solution

l quantities of "A" and "B," and try to identify the precipitate formed by means
properties of substances listed in handbooks.

n to the large number of possible compounds that were excluded because of their
to precipitate easily.

pitated Ions

solutions of Na_2CrO_4, $Pb(NO_3)_2$, $NaNO_3$, $Mg(NO_3)_2$, and $AgNO_3$, and a 1 M HCl solution.
which metallic ions can be precipitated as chlorides or as chromates, which
e in hot water, which in concentrated ammonium hydroxide (use the hood), and which

containing both Pb^{++} and Ag^{+} ions, and ask them to separate the two ions and give
ach.

es by Precipitation

ilver nitrate solution on halogen ions. Repeat the process using lead nitrate
behavior of the silver and lead halides in sunlight, and compare their solubilities
HNO_3.

Ask the pupils to suggest a test for Cl^-, Br^-, and I^-.

A 8.04 Making a Simple Spectroscope

Obtain a cardboard tube such as found in a roll of wax paper. At one en
containing a narrow slit. At the other end, mount a plastic replica gra

In a darkened room,look through the tube to see spectral lines produced
in spectral tubes.

A 8.05 Identification of Unknowns by Flame Tests

Have available solutions of each of the following ions: Li^+, Sr^{++}, Ca^{++}
number of unknown mixtures labeled unknown 1, 2, 3, etc.

1. K^+, Na^+
2. Li^+, Ba^{++}
3. Cu^{++}, K^+, Na^+
4. Li^+, Ba^{++}, Na^+
5. Li^+, Sr^{++}, Ca
6. blank (distill
7. An ion not in
an excellent f

Provide the pupils with some glass filters, and ask them to identify as
mixture. (Do not expect all ions in all solutions to be identified.) I
some results. Only spectrographic analysis can give a positive identifi

A 8.06 Influence of Developers

Several tapered strips of filter paper are cut to fit 6-inch test tubes.
end, place a tiny spot of green cake-coloring dye which can be purchased
tube, put 1 ml. of distilled water, in another put 1 ml. of n-butanol, a
butanol-acetic acid (glacial) - water, 4:1:2 (v/v/v). Insert and suspen
end is immersed, but do not allow the color spot to dip into the solvent
polar dye with the solvent front. Relatively nonpolar butanol has no ef
marked zones. The polarity of a mixture of water and glacial acetic is

The butanol-acetic acid solvent should be made just before class as the

If too large a spot of dye is used, distinct zones will not be obtained.

r Cl^-, Br^-, and I^-.

nd in a roll of wax paper. At one end, fasten a piece of cardboard
ther end, mount a plastic replica grating.

tube to see spectral lines produced by colored flames or excited gases

e Tests

f the following ions: Li^+, Sr^{++}, Ca^{++}, Ba^{++}, Cu^{++}, K^+, and Na^+. Have a
unknown 1, 2, 3, etc.

5. Li^+, Sr^{++}, Ca^{++}
6. blank (distilled water)
7. An ion not in standard set up. Indium will give an excellent flame.

filters, and ask them to identify as many ions as possible in each
in all solutions to be identified.) Interference of colors will obscure
analysis can give a positive identification.

paper are cut to fit 6-inch test tubes. At about 1 cm. from the tapered
ake-coloring dye which can be purchased at a grocery store. In one test
r, in another put 1 ml. of n-butanol, and in the third put 1 ml. of a
ater, 4:1:2 (v/v/v). Insert and suspend the paper strips so the tapered
the color spot to dip into the solvent. Highly polar water moves the
Relatively nonpolar butanol has no effect. The mixture produces well-
mixture of water and glacial acetic is "reduced" by the n-butanol.

hould be made just before class as the solvent mixture is unstable.

ed, distinct zones will not be obtained.

A 8.07 Selection of Solvent and Adsorbent

Since there is no way to predict the best choice of an adsorbent or s
graphic separation of a mixture, the selection must be worked out by

Select an adsorbent, paper or Silica Gel G layer (See 8.10), preferab
mixture of dyes, such as found in food coloring, a few centimeters ap
tube, add dropwise a small quantity of solvent and observe any separa
moves out from the spot. Repeat the process using a different solven
the best separation should be used on that adsorbent.

If time permits, the process may be repeated using another adsorbent w
Probably, the results will show that the same solvent will not give th
both adsorbents.

A piece of glass tubing with one end drawn out into a capillary tube m
dropping solvent or spotting the mixture.

Some solvents often used in separations are benzene, benzene-acetone (
benzene-acetone (8:2, v./v.); n-butanol, acetone, methanol, and water.

Be sure to use the hood for many of the solvents are flammable and/or

A 8.08 Making an R_f Table

An R_f table lists the R_f values for various substances on a specific a
used.

Before class, determine the solvent(s) which will separate on a specif
(See A 8.07)

Each pupil spots a known dye on the adsorbent, develops the chromatogr
(Remind pupils to mark the solvent front as soon as the adsorbent is r
tank.) Have the class list the average R_f for the dye on the chart.
for other dyes.

The table can be expanded by repeating the above but using a different
second column.

nt

the best choice of an adsorbent or solvent to be used during the chromato-
the selection must be worked out by trial and error.

lica Gel G layer (See 8.10), preferably. Put several tiny drops of a
n food coloring, a few centimeters apart on the adsorbent. From a capillary
ity of solvent and observe any separation which may occur as the solvent
the process using a different solvent on each spot. The solvent giving
ed on that adsorbent.

be repeated using another adsorbent with the solvents previously tested.
that the same solvent will not give the best separation of the mixture on

end drawn out into a capillary tube makes an excellent pipette for
mixture.

rations are benzene, benzene-acetone (8:2, v./v.); petroleum ether,
butanol, acetone, methanol, and water.

of the solvents are flammable and/or have toxic vapors.

for various substances on a specific adsorbent when different solvents are

ent(s) which will separate on a specific adsorbent a mixture of known dyes.

the adsorbent, develops the chromatogram, and calculates the R_f value.
nt front as soon as the adsorbent is removed from the developing dish or
average R_f for the dye on the chart. Repeat the process to obtain values

eating the above but using a different solvent. The data obtained makes a

Remind pupils that the title of the table must mention the general class of sub while each column of values must be labeled with the solvent system used to obt

If time permits, unknown mixtures containing one or more dyes can be separated fied on the basis of the R_f values.

A 8.09 Thin Layer Chromatography

Silica Gel G makes a very satisfactory thin-layer adsorbent. It can be purchas plastic sheets which can be cut into small strips for pupil use.

The Gel can also be purchased in powder form, slurried, and spread on microscop made by mixing 1 part of Silica Gel G with 2 parts (by weight) of distilled or amount of the slurry is put on one end of the slide and quickly spread by drawi stirring rod across the slide. With a little practice, fairly uniform layers c dried in air in several minutes or in an oven at 110°C. for 10 minutes.

Since Silica Gel G contains a binder of plaster of paris, the slurry should be mixed.

With a sharp pencil point or pin, prick the film about 1 cm. from the edge of t or slide. This mark will show the starting point, and a drop of mixture should spot has dried, stand the film in a screw-cap jar or 250-ml. beaker containing Cover the container to keep the atmosphere saturated with solvent. After the s 3/4 of the height of adsorbent, remove the film and mark the solvent front.

The R_f value of each component can be calculated: $R_f = \frac{\text{distance component move}}{\text{distance solvent moved}}$

By comparison with R_f tables for the solvent-adsorbent system listed in most ch comparison with known samples run along with the mixture on the film, the compo

TLC can be used to separate chlorophyll and xanthophyll components of plants. the materials can be obtained from the Biology Handbook.

Mixtures of dyes or amino acids are also separated by TLC. Amino acids are det developed chromatogram with ninhydrin reagent which can be obtained in aerosol supply companies.

e of the table must mention the general class of substances and the adsorbent, must be labeled with the solvent system used to obtain the values.

xtures containing one or more dyes can be separated and some components identi- values.

atisfactory thin-layer adsorbent. It can be purchased ready to use as a film on cut into small strips for pupil use.

ed in powder form, slurried, and spread on microscope slides. The slurry is lica Gel G with 2 parts (by weight) of distilled or de-ionized water. A small on one end of the slide and quickly spread by drawing or rolling a glass de. With a little practice, fairly uniform layers can be made. The films are utes or in an oven at 110°C. for 10 minutes.

a binder of plaster of paris, the slurry should be spread as soon as it is

r pin, prick the film about 1 cm. from the edge of the narrow width of the strip how the starting point, and a drop of mixture should be placed on it. After the ilm in a screw-cap jar or 250-ml. beaker containing a shallow layer of solvent. the atmosphere saturated with solvent. After the solvent has traveled about ent, remove the film and mark the solvent front.

ent can be calculated: $R_f = \frac{\text{distance component moved from starting point}}{\text{distance solvent moved from starting point}}$

for the solvent-adsorbent system listed in most chromatography texts or by es run along with the mixture on the film, the components can be identified.

chlorophyll and xanthophyll components of plants. Directions for extracting ed from the Biology Handbook.

ids are also separated by TLC. Amino acids are detected by spraying the ninhydrin reagent which can be obtained in aerosol cans from most scientific

A 8.10 Amino Acid Separation

Prepare air dried silica gel layers, and spot with the amino acid r the film. (See Activity A 8.09 for preparing, spotting the adsorbe Develop the film in a chamber containing a mixture of n-butanol/gla volume). When the solvent has moved about 10 cm. from the initial solvent front, and dry the film in air. Then heat the film in an c warm, dried film with ninhydrin reagent. (Reheat if necessary to b spots.)

Handle all films by the edges to avoid adding contaminating amino a

Pupils may encounter difficulty in identifying amino acids from R_f the values are affected by concentration. A more positive identifi "spots" with those obtained by simultaneously running chromatogram

Pupils may find a challenging laboratory experience in separating a fresh cucumber juice or tree sap.

A 8.11 Determining the Amount of CO_2 in a Substance

Assemble a gas generator and apparatus for collecting a gas by dis vessel for collection of the gas. In the interests of safety, wra tape and use a thistle tube.

Check the volume of water displaced in the collecting vessel as 10 generator. The displaced volume caused by any solution being adde from any gas volume.

Place a tablet or powder of an effervescing antacid substance use generator. Add the 100 ml. of water, and collect the CO_2 produced.

Find the factors that affect the amount of gas formed.

Vary the amount and temperature of the water added to the generato the collecting apparatus. This should give an opportunity to disc variables except the one being investigated in an experiment.

el layers, and spot with the amino acid mixture about 1-2 cm. from the edge of
8.09 for preparing, spotting the adsorbent, and developing a chromatogram.)
ber containing a mixture of n-butanol/glacial acetic acid/water (4:1:1 by
has moved about 10 cm. from the initial spot point, remove the plate, mark the
film in air. Then heat the film in an oven at 110°C. for 10 min. Spray the
ydrin reagent. (Reheat if necessary to bring up the color reaction with the

dges to avoid adding contaminating amino acids from the skin.

iculty in identifying amino acids from R_f values found in reference tables, since
y concentration. A more positive identification can be made by comparing the
ed by simultaneously running chromatograms of known amino acids on the same plate.

ging laboratory experience in separating and identifying the amino acids found in
ree sap.

CO_2 in a Substance

and apparatus for collecting a gas by displacement of water. Use a calibrated
the gas. In the interests of safety, wrap the generator bottle with a towel or
ube.

r displaced in the collecting vessel as 100 ml. of water are added to the
d volume caused by any solution being added to the generator should be subtracted

of an effervescing antacid substance used for stomach disorders into the dry
ml. of water, and collect the CO_2 produced.

ffect the amount of gas formed.

erature of the water added to the generator and the temperature of the water in
. This should give an opportunity to discuss the necessity for controlling all
being investigated in an experiment.

A 8.12 Making a Series of Dilutions

In a 100-ml. volumetric flask containing about 75 ml. of hot water, d
crystals. Cool the solution, and adjust its volume to 100 ml. Label

Make the first dilution. Transfer by a volumetric pipette 10 ml. of
volumetric flask. Add water to adjust the volume to 100 ml. Label t

The second dilution is made by using the same technique to transfer 1
increase its volume to 100 ml. Label this solution 0.002 g./ml.

Successive dilutions are made until the eye can no longer distinguish

Use the dilutions to demonstrate a simple colorimeter. Compare 10-ml
of an unknown concentration of the same solute. The unknown concentra
the standard which most closely matches the color of the unknown.

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containing about 75 ml. of hot water, dissolve 20 grams of copper sulfate
and adjust its volume to 100 ml. Label this solution 0.2 g./ml.

sfer by a volumetric pipette 10 ml. of the 0.2 g./ml. solution to a 100-ml.
o adjust the volume to 100 ml. Label this solution 0.02 g./ml.

using the same technique to transfer 10 ml. of 0.02 g./ml. solution and
Label this solution 0.002 g./ml.

until the eye can no longer distinguish any color to the solution.

te a simple colorimeter. Compare 10-ml. samples of the dilutions with 10 ml.
the same solute. The unknown concentration will be approximately equal to
y matches the color of the unknown.

APPENDIX B - BIBLIOGRAPHY OF CHEMISTRY REFERENCE MATERIA

Among the many reference books available, the following may be used by teachers f

General

Crespin, F. S. *Dictionary of technical terms.* New York. D. Bruce. 1948.

Grant, J. S. *Hackh's chemical dictionary; 3d ed.* New York. Blakiston. 1944.

Gray, C. H. *Laboratory handbook of toxic agents.* Prentice-Hall. 1961.

Manufacturing Chemists' Association, Inc. *Guide for safety in the chemical labora*
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Area 6

American Petroleum Institute. *Conserving our waters and clearing the air.*

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American Public Health Association. 1965.

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for junior and senior high school science classes. Pennsylvania. Air P

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____ *Manual of instruction for water treatment plant operators.* Albany.

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APPENDIX C - FILMS AND FILMSTRIPS

Among the many films and filmstrips which may be used are the followi

AREA I - Similarities and Dissimilarities of Matter

Films:

Cor Chemical bonds and atomic structure
 Chemistry Laboratory techniques series:
 Introduction to the Chemistry Laboratory
 Bunsen burner
 Glass tubing
 The test tube
 The reagent bottle
 Solids
 Filtration
 Acids
 Vapors
 The Blowpipe
 Safety in the laboratory
Cor Elements, compounds, and mixtures
Cor The halogens (2d ed.)
M Family of halogens
SM Fun in metals
Cor Ionization
BU Magic of sulfur
Cor Metals and nonmetals
Cor Preparation and properties of halogens
Cor The sodium family
Cor Solutions
Cor Sulfur and its compounds

Film loops:
E Chemistry Laboratory Technique Series
 Bunsen burner
 Heating solids
 Heating liquids
 Weighing on a two-pan balance
 Filtration
 Use of a burette
 Use of a pipette
 Working with glass

Filmstrips:
EBF Electron arrangement and chemical bonds
EBF Ionic and covalent bonds
EBF Ionization and dissociation

AREA II - The Prep

Films:
EBF Electro
EBF Oxidati
M Oxidati
Cor Propert
Cor Propert
Cor Standar
M Structu

Filmstrips:
M Chemica
M Equatio
M Laborat
M Periodi

AREAS III and IV -

Films:
S Crude o
Cor Hydroca
P Make me
S Refinin
BU Story o

Filmstrips:
M Hydroca

AREA V - Chemistry

Films:
A Effect

AREA VI - Environme

Films:
NM Air pol
 (3 pa

C - FILMS AND FILMSTRIPS

may be used are the following:

er

es:
ratory
ion

wpipe
in the
atory

ns

s

nds

AREA II - The Preparation and Separation of Substances

Films:

EBF	Electrochemistry
EBF	Oxidation and reduction
M	Oxidation - reduction
Cor	Properties of water
Cor	Properties of solutions
Cor	Standard solutions and titrations
M	Structure of water

Filmstrips:

M	Chemical formula
M	Equations
M	Laboratory techniques
M	Periodic table

AREAS III and IV - Organic Compounds

Films:

S	Crude oil distillation
Cor	Hydrocarbons and their structure
P	Make me useful
S	Refining oil for energy
BU	Story of gasoline

Filmstrips:

M	Hydrocarbons

AREA V - Chemistry in the Home

Films:

A	Effect of heat on milk

AREA VI - Environmental Pollution

Films:

NM	Air pollution: take a deep deadly breath (3 parts)

EC	Better water for Americans
PHS	Control of air pollution MIS 676
PHS	Effects of air pollution MIS 678
IS	Endless search (scrap processing)
EC	Finding out about the water cycle
PHS	George Washington's river MIS 525
Cor	Hard water
A	It's your decision - clean water
EC	Municipal sewage treatment processes
BR	New water for a thirsty world
MT	Pure water and public health
RH	Role of ion exchange
EC	Sanitary landfill - open dump conversion
PHS	Sources of air pollution MIS 677
EC	Take a deep breath
S	The river must live
NM	The third pollution (Land pollution)
AP	To clear the air
EC	Wise use of water resources
EC	With each breath

Filmstrips:

W	Environmental pollution...our world in crisis

AREA VII - Some Modern Materials

Films:

AEC	Art of separation (radio-chromatography)
AEC	Atomic cities
US	Blast furnace
UC	Case of the fantastic plastic
BU	Copper, the oldest modern metal
FM	FMC Fibers and films
AEC	Isotopes (production and handling)
USA	Lead from mine to metal
G	Magic touch (polymerization)
AEC	Man and radiation (application)
C	Manufacturing reinforced plastics
R	New world of chemistry
G	New world of rubber

F	Of mer
BT	Physic
AEC	Radiat
AEC	Radio
DN	Report
BU	Silver
AEC	The ne
AEC	Unders Alph Radi Prop

AREA VIII - Chemi

Films:

AEC	Art o
M	Princ

for Americans
ir pollution MIS 676
ir pollution MIS 678
ch (scrap processing)
about the water cycle
ngton's river MIS 525

cision - clean water
wage treatment processes
r a thirsty world
nd public health
exchange
dfill - open dump conversion
ir pollution MIS 677
breath
t live
llution (Land pollution)
air
ater resources
eath

pollution...our world in

terials

tion (radio-chromatography)

antastic plastic
ldest modern metal
and films
duction and handling)
e to metal
polymerization)
tion (application)
reinforced plastics
chemistry
rubber

F Of men and molecules
BT Physical chemistry of polymers
AEC Radiation in perspective (radiation hazard)
AEC Radioisotopes - safe servants of industry
DN Report on DuPont elastomers
BU Silver
AEC The new power (power reactor)
AEC Understanding the atom series:
    Alpha, beta, gamma
    Radiation and matter
    Properties of radiation
    Detection by ionization
    Detection by scintillation
    Nuclear reactions

AREA VIII - Chemical Analysis

Films:
AEC Art of separation (chromatography)
M Principles of chromatography

KEY TO SOURCES

The companies listed in the key below lend the films in Appendix
request, supply complete lists of their films.

(A) Association Films
347 Madison Ave.
New York, N.Y. 10017

(AEC) U.S. Atomic Energy Commission
New York Operations Office
Public Information Service
376 Hudson St.
New York, N.Y. 10014

(AP) American Petroleum Institute
Committee on Public Affairs
1271 Avenue of the Americas
New York, N.Y. 10020

(Cor) Coronet Films
42 Midland Rd.
Roslyn Heights, N.Y. 11577

(D) Disraeli Films
P.O. Box 343 - Cooper Station
New York, N.Y. 10003

(DN) DuPont de Nemours and Co., Inc.
Motion Picture Section
Advertising Dept.
1007 Market St.
Wilmington, Del. 19898

(E) The Ealing Corp.
Cambridge, Mass. 02140

(BR) Bureau of Reclamation
Office of Chief Engineer
Building 67
Attn.: D-841
Denver Federal Center
Denver, Colo. 80225

(BT) Bell Tel
(contac

(BU) Bureau o
United S
Graphic
4800 For
Pittsbur

(C) Carborun
Attn.:
Niagara

(EBF) Encyclop
38 W. 32
New York

(EC) New York
Film Lib
50 Wolf
Albany,

(F) Farm Fil
1425 H S
Washingt

(FM) FMC Corp
American
Product
1617 Joh
Philadel

(G) Goodyear
A.V. Dep
Akron, O

KEY TO SOURCES

ey below lend the films in Appendix C. Many of these companies will, upon
eir films.

(BT) Bell Telephone Company
(contact local telephone office)

(BU) Bureau of Mines
United States Department of Interior
Graphic Services
4800 Forbes Ave.
Pittsburgh, Pa. 15213

(C) Carborundum Co.
Attn.: Mr. W. Evans
Niagara Falls, N.Y. 14302

(EBF) Encyclopeadia Britannica Films
38 W. 32nd St.
New York, N.Y. 10001

(EC) New York State Environmental Conservation Dept.
Film Library
50 Wolf Road
Albany, N.Y. 12201

c.

(F) Farm Film Foundation
1425 H St., N.W.
Washington, D.C. 20005

(FM) FMC Corporation
American Viscose Division
Product Information
1617 John F. Kennedy Blvd.
Philadelphia, Pa. 19103

(G) Goodyear Tire and Rubber Co.
A.V. Department
Akron, Ohio 44316

(IS) Institute of Scrap Iron and Steel
Public Relations Department
1729 H St., N.W.
Washington, D.C. 20006

(M) McGraw Hill
330 W. 42nd St.
New York, N.Y. 10036

(MT) Modern Talking Picture Service
122 West Chippewa St.
Buffalo, N.Y. 14202

(NM) National Medical Audiovisual Center (Annex)
Station K
Atlanta, Ga. 30324

(P) Pure Oil Co.
Film Library
200 E. Golf Road
Palastine, Ill. 60067

(PHS) Public Health Service
Communicable Disease Center
Atlanta, Ga. 30300

(R) Reichhold Chemicals, Inc.
Att.: L. Welles, A.V. Department
525 N. Broadway
White Plains, N.Y. 10602

(RH) Rohm and Haas Company
Redstone Research Lab
Huntsville, Ala. 35807

(S) Shell Oil Company
Film Library
149-07 Northern Blvd.
Flushing, N.Y. 11354

(SM) American Society for Metals
Attn.: Mr. T. C. DuMond
Metals Park, Ohio 44073

(UC) Uniroyal Chemical
Public Relations Dept.
Chemical Division
Naugatuck, Conn. 06770

(US) United States Steel Corporation
New York Film Distribution Center
71 Broadway
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